Taking a Lean Thinking Perspective

TU Delft U.PORTO

Crucial actions in design

Coping with critical situations

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'The minds of the Utopians, when fenced with a love for learning, are very ingenious in discovering all such arts as are necessary to carry it to perfection. Two things they owe to us, the manufacture of paper and the art of printing; yet they are not so entirely indebted to us for these discoveries but that a great part of the invention was their own. We showed them some books printed by Aldus, we explained to them the way of making paper and the mystery of printing; but, as we had never practised these arts, we described them in a crude and superficial manner. They seized the hints we gave them; and though at first they could not arrive at perfection, yet by making many essays they at last found out and corrected all their errors and conquered every difficulty.'

As described by the Portuguese traveler Raphael in,

Utopia

Thomas More

First printed at Louvain under the editorship of Erasmus of Rotterdam in 1516

From The Project Gutenberg eBook based on Gilbert Burnet's English translation in 1684

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Summary

This doctoral thesis proposes ways for the translation of the Lean Thinking (LT) into design practice and research, taking the LT concepts as dimensions to study designers' behavior across design disciplines. Lean Thinking has its roots in manufacturing, however, as a philosophy of guiding principles of *Value* creation, LT has been applied to a large variety of processes, people and organizations. Despite the implementation success achieved in several fields of practice and research, the translation of LT Principles to design has several problems to overcome. But as a motivational framework LT provides concepts, which are relevant to the design activity and in particular to the assessment of designers' behavior and performance. This research takes the LT perspective, adopting the concepts of Lean Principles, such as *Value* and *Flow,* and the concept of *MUDA* (the Japanese word for waste) for studying designers in the context of interaction with stakeholders in design and product development processes. As in the design activity, *Value* is not completely defined in the beginning of the *Value* creation process, this thesis claims the importance of adopting Lean Principles within *crucial actions* for an effective *Value* definition. The empirical part of this research comprises of case studies in five design disciplines. Based on these studies, the translation of the Lean Principles and *MUDA* in design leads to categorization systems and to the concept of *critical situations*. Results integrate a framework of awareness to *critical situations* and *crucial actions* in design. This thesis proposes a motivational approach for designers that help them improve performance in *Value* creation. The framework of awareness provides a meta analysis and challenges designers and developers to reflect upon their thinking and acting and on what prevents them from changing behavior to reach an effective performance. The use of the framework in practice might improve designers' and developers' adaptive behavior and so contribute to professional competence and education.

Samenvatting

In dit proefschrift worden voorstellen gedaan voor de vertaling van Lean Thinking (LT) naar de praktijk en het onderzoek van het ontwerpen en worden LT concepten ingezet om het het gedrag van ontwerpers te bestuderen, dwars door ontwerpdisciplines heen. Lean Thinking heeft zijn wortels in de maakindustrie, maar als een filosofie van richtinggevende principes is LT in een grote verscheidenheid aan processen, mensen en organisaties toegepast. Niettegenstaande de succesvolle implementatie in verschillende gebieden van praktijk en onderzoek, moeten bij de vertaling van LT principles naar het ontwerpen verschillende problemen overwonnen worden. Maar als een motiverend denkkader biedt LT concepten die relevant zijn voor ontwerpactiviteiten en in het bijzonder voor de beoordeling van het gedrag en de prestaties van ontwerpers. In dit proefschriftonderzoek worden de concepten van Lean principles zoals *Value* and *Flow* en het concept *MUDA* (het Japanse woord voor afval) benut als invalshoeken om ontwerpers te bestuderen in de context van interactie met stakeholders in design en productontwikkeling. Bij het ontwerpen is *Value* aan het begin van het waardecreatieproces niet volledig gedefinieerd. Daarom wordt in dit proefschrift het belang benadrukt van het toepassen van Lean principes in *cruciale acties* voor een effectieve *Value* definitie. Het empirische deel van dit onderzoek bestaat uit case studies in vijf ontwerpdisciplines. Op basis van deze studies leidt de vertaling van de Lean principes en *MUDA* naar het ontwerpen tot categoriseringsystemen en het concept van *kritieke situaties*. De resultaten zijn geintegreerd in een bewustzijnskader voor *kritieke situaties* en *cruciale acties* bij het ontwerpen. Dit proefschrift biedt aan ontwerpers een motiverende werkwijze voor het creëren van waarde. Het kader voorziet in een meta-analyse en stimuleert ontwerpers en ontwikkelaars om te reflecteren op hun denken en handelen en op wat hen ervan weerhoudt hun gedrag te veranderen om de effectivieit ervan te vergroten. Het gebruik van het kader in de praktijk kan het adaptieve gedrag van ontwerpers en ontwikkelaars verbeteren en bijdragen aan de ontwikkeling van professionele competenties en het beroepsgerichte onderwijs.

1 Introduction

The fundamentals of this thesis rely on the need to study designers' behavior to improve designers' performance. With such purpose, this research presents an exploratory approach to design, taking the perspective of the Lean Thinking philosophy. This doctoral thesis explores how far Lean Thinking has applicability in design, a proposition that is investigated with empirical studies. The thesis claims the importance of effectiveness in all the stages and activities of design and product development processes, including the creative ones, and Lean Principles as elements of *crucial* actions for an effective *Value* definition.

1.1 Motivation

'Conscientious and careful physicians allocate causes of disease to natural laws, while the ablest scientists go back to medicine for their first principles.'

Attributed to Aristotle

While working as an architect and industrial designer, I participated in many projects involving design teams, offices and stakeholders. During this time, I experienced and observed the manner in which some projects were effectively and satisfactorily accomplished, while others were not. The less successful projects suffered from complicated management where risks were taken without informed understanding, opportunities were missed, design purposes were neglected, management dexterity was absent, coordination efforts were not well succeeded, and adaptability was not properly considered. These faults lead to ineffective design processes and discouraging design outcomes. The awareness to such causes and effects towards the end result of projects increased my interest in better understanding and learning how to cope with the incongruities of the design practice. While pursuing my interest to improve and contribute to the methodology of the design practice, I was challenged to think about Lean Thinking (Womack et al., 1990, 1996, 2nd ed. 2003) in design.

For the unacquainted, Lean Thinking (LT) is a domain-independent philosophy based on five principles, namely *Value, Value Stream, Flow, Pull* and *Perfection* with the purpose of eliminating *MUDA* in any *Value* creating activity. *MUDA*, the Japanese word for waste, is defined as *'specifically any human activity which absorbs resources but creates no value'* (Womack et al., 2003, p. 355). *Value* is defined at the start and *MUDA*, if inevitable, is converted into *Value*. Lean Thinking derived from the manufacturing context, with a philosophy of guiding principles of behavior that has applicability to a large variety of processes, people and organizations (Walton, 1999) with demonstrated practical results (Oehmen et al., 2012). Progress has been made in implementing and raising awareness of LT in several fields of practice and research, and it has been expanded to product development processes (Oehmen et al., 2011). However, a gap in the understanding and linking of Lean Principles and the creative dimension of design has been identified. In design, the development of final concepts and solutions, may not have been reached without discarding others, therefore some *MUDA* is necessary. As a motivational framework, LT provides concepts relevant to the design activity and to designers' behavior and performance, such as the dimension of *Flow* (Csikszentmihalyi, 1990, 1996, 1997).

Taking the Lean Thinking principles to identify what is ineffective in design processes, was initially seen as a challenge similar to identifying the pathologies of designing: its causes, effects, typical behavior and coping measures. The analogy of the pathological approach seemed to make sense. At the same time, designers' sustainability concerns and talent to create *Value* from waste, unintentionally makes them Lean Thinking enablers (Oehmen et al., 2012) in a world that disregards and keeps generating *MUDA*. However, some limitations emerged. The Lean Thinking aim for straightforward efficiency and immediate effectiveness was initially blurring the advance of the research.

The design process is iterative and recursive by nature (Cross and Roozenburg, 1992), and like the '*Utopians*', designers also '*seize the hints*' and '*know at first that they can not arrive at perfection*'. Although generally considered as unattainable or intangible, humans pursue perfection in almost everything they do. 'By *making many essays*' designers pursue perfection through iteration in the design process, correcting all the inaccuracies and hoping to '*conquer every difficulty*' concerning the final result.

Lean Thinking represents an ancient way of being and pursuing effective *Value* definition for an efficient process. In design the importance of being effective exists in any stage including the creative ones, where designers can easily lose direction, or having great ideas without knowing how to implement them leading to *Value* loss. From a research implementation point of view, Lean Thinking seemed to be the adequate motivational framework to identify characteristics of less effective processes and coping actions to up-hold performance, assuming first and foremost that design is a process where *Value* is not completely defined in the beginning,

> *'The final outcome of designing has to be assumed before the means of achieving it can be explored.'*
>
> Christopher Jones, 1970. *Design Methods.* p. 10

This unavoidable assumption opened the way for the translation of Lean Thinking into design as an activity that assumes and explores *Value* variables, where uncertainty and risk play a resilient game.

Adopting a Lean Thinking perspective does not mean applying its principles to rule or constrain the design activity. This thesis takes the Lean Thinking concepts to a higher level of *Value* creation that relates to the search for variables of what is not known while designing *Value.* What for some would be a fictional application, slowly became possible and framed for its main audience of design practitioners, developers, educators and researchers, and secondly, to whom might be interested in improving performance in its own activity.

1.2 Research Field

This doctoral research takes the Lean Thinking perspective adopting the Lean principles and the central concept of *MUDA* (waste) as dimensions to study designers' behavior in the research field of design and product development.

Design is a thought process and some professions take it as its core activity in the reflective practice (Schön, 1983; Schön, 1988) of design implementation. Designers frame design choices, moves and course of actions for a certain *Value* set determined by given objectives and design purposes. Taken paths sometimes lead to critical or uncertain stages, and designers have to move back and forward while characterizing the *Value* of their solutions.

In the context of this thesis, designing is a *Value* creation activity along a purposeful, creative, organized and business oriented process with a dynamic in time. This thesis supports the premise that designing can be studied as a distinct activity that transcends disciplinary boundaries (Cross, 1982; Visser, 2009). Design, as an activity entails mental and physical actions and designers have to manage these actions to be able to cope gainfully with the social process of designing in a business context.

The context of the design activity is rich in situations that create influences and consequences in designers' behavior and performance while managing the underlying mechanisms of *Value* creation. In design, as in life, these situations take place due to unforeseen influences and consequences, lack or excess of prevention, a mind frame that does not allow to see further or refuses a sudden aspect of the process.

On a daily basis, designers' have to stand for situations such as, postponement, encumbrance, impediment, emergency and surprise. Occasionally some of these situations lead to valuable inputs essential to the design process, although designers are not always prepared to attempt and succeed in taking the best from these situations. Inherent to the occurrence of downside consequences is the risk of diminishing designers' input of *Value* for the creation of design results in circumstances comparable to the concept of *MUDA* (waste). In many of these instances, designers do not grasp a reaction to cope with the quandary leading to missteps. In other circumstances, designers are able to evaluate the dynamics of the situation and make the appropriate decisions to proceed. The first case is our main concern, the second case is our goal: to support designers with empirically derived knowledge on adaptive behavior to improve performance toward decision-making in situations of *MUDA* in design. Designers play an important role in the *Value* creation in design and product development of objects and surroundings of everyday life (Perks et al., 2005) thus they should not be left without support in such circumstances.

Adopting the LT perspective as a theoretical frame provided a lens and the opportunity to approach design across its host disciplines (Love, 2002). The benefits of using the LT approach are:

- Lean Thinking as a theoretical background provides a non-discipline-related way to approach design.
- The idea of eliminating *MUDA* along the design process is both specific and common, and entails situations to be supported.
- Adopting the Lean Principles to study design provides assessment to how designers' thinking and actions enhance the *Value* of the design process and design results.

As LT has formed a motivational approach to keep procedures of *Value* creation at a high standard, this thesis proposes a motivational approach to keep designers' behavior at a high performance.

1.3 Scope

Lean Thinking is a philosophy of guiding principles of behavior (Walton, 1999) for the business context where aspects such as quality, flow, time and cost play an important role in the creation of *Value*. Such elements are also of major importance for the designing activity under the pressures of the business context, as design has, by far, the biggest influence on cost, quality and time-to-market.

Taking the opportunity of such confluence as a theoretical frame, Lean Thinking facilitates a principles-based and multidisciplinary approach to the study of designers' behavior and consequent management implications to designers' decision-making. This research aims to widen the scope of the Lean Thinking philosophy. The foremost expected contribution of the present doctoral research is three-fold:

- First, to extend the Lean principles to design and product development.
- Second, the creation of an explanatory framework of Lean principles and *MUDA* within the actors of design contexts.
- Third, findings aim to enhance the knowledge about designers' across disciplines and improve behavior.

In addition, the current context of economic crisis was revealed to be the appropriate field to assess and derive knowledge of designers' behavior as they activate mechanisms that remain hidden in times of normal circumstances (Vieira et al., 2010b). Elements of effective design action can best be deciphered under circumstances that represent design on the edge of feasibility, where results emerge through essential human understanding (Flusser, 1999).

1.4 Research Objectives

To investigate the usefulness of the Lean principles in design, the doctoral research proposes the Lean Thinking concepts of *MUDA* and Lean Principles as dimensions of analysis to study designers. The doctoral researcher accomplished activities considered in five major groups, namely Research background, Empirical study, Data analysis, Synthesis and Evaluation to support the achievement of the following research objectives, namely:

- Identification of Lean principles and *MUDA* (waste) in design:
  - Primarily based on comparable *MUDA* situations, *Value* from designers' point of view and *Value Stream* as designers' approach characteristics.
  - Identification of designers' *Flow* conditions and *Pull* inputs in *MUDA* situations.
- Translation of Lean Principles in design across disciplines.
- Development of an explanatory framework.

1.5 Dissertation Overview

The thesis is structured in seven chapters outlined in the next paragraphs. The sequence of chapters attempts to guide the reader into the usefulness, identification, assessment, analysis, integrated results and translation of the Lean Principles and *MUDA* in design. A visual supports the synopsis (Figure 1.1).

Chapter 1: Introduction. As a summary of the present chapter, these initial pages explain the motivation, limitations of the research approach, the research field of design and product development, the scope of the contribution, research objectives, and the description and illustration of the thesis structure.

Chapter 2: Theoretical Background. The chapter provides the theoretical background supporting the research, depicting a more detailed connection between design and the Lean Thinking philosophy. Then, describes streams of research approach for the translation of Lean principles and *MUDA* into design. The chapter poses the research question and sub-questions and the relevance and limitations of identifying invariants of designers' behavior.

Chapter 3: Research Methods. The chapter describes the research approach, explaining its philosophical stance, selected research methods and case studies, researcher role and intervention, assessment of research objectives, data collection, data processing, coding and clustering procedures, data analysis across the studies, and overview of single and cross-case analysis.

Chapter 4: Case Studies Description. The empirical studies derive from case studies described in the fourth chapter of the thesis. Evidence is given to similarities, differences, complementarities and specificities of each case study following a common structure of description.

Chapter 5: Analysis and Results. The chapter explains and describes the analysis across the studies, its connection to the research question and sub-questions, evolution and integration of results and achievement of central categorization systems.

Chapter 6: Discussion. The chapter depicts the findings derived from the research studies based on categorization systems integrated in a Framework of Awareness. The translation and definition of the Lean principles and *MUDA* in design are proposed.

Chapter 7: Conclusion. This chapter concludes with the research knowledge contributions, implications to design management and design education, and limitations and further research.

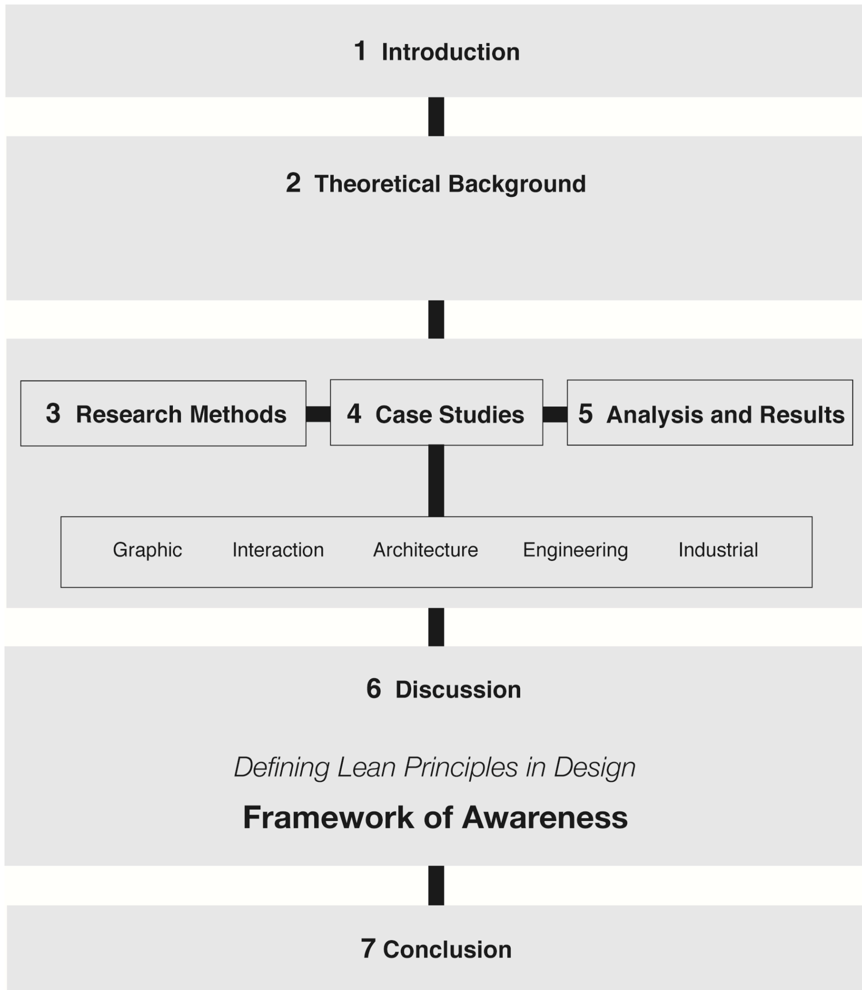

Figure 1.1. Illustration of the structure of the thesis

Chapter 2 covers research issues playing a role in the connection between design and Lean Thinking namely, *Value* in design, design approach, *Flow*, variants and invariants of behavior in design, such as valuation and decision-making. Explanation is given to the adoption of the Lean Thinking perspective. Substantiation is given to the Lean principles *and MUDA* as drivers for the translation of Lean Thinking into design. Relevance and limitations of identifying invariants of designers' behavior are portrayed. The chapter is concluded with the research question and sub-questions.

2 Theoretical Background

2.1 Lean Thinking

Different philosophies derived from the Engineering field tackle the issues of efficiency and effectiveness such as Lean Manufacturing (Womack et al., 1990, 2007) focused on the elimination of waste (*MUDA)* in *Value* creation processes, Six Sigma on a quality-based initiative (Tennant, 2001), and the Theory of Constraints concerned with bottlenecks in processes (Goldratt, 1997). These management philosophies, based on theoretical systems that characterize the achievements of Japanese management practices, became known as the Toyota Production System (TPS, Ohno, 1988), Total Quality Management (Bounds, 1994), and Lean Thinking (Womack and Jones, 1996, 2003), led to a growing number of tools and support systems with application in project management and product development processes (Oehmen et al., 2011, 2012). The aim is to achieve higher levels of quality, efficiency and morale.

This thesis speculates and proposes that Lean Principles constitute human being and that the Lean approach extends beyond providing a kind of efficiency and improvement in any industrial process. People probably have been thinking about eliminating waste *(MUDA)* or converting waste into *Value*, since they came into being. Adopting the Lean Thinking perspective as a theoretical frame provides the idea of eliminating *MUDA* along the design process, which is specific and common across design activities and entails situations to be supported. Adopting the Lean Principles to investigate the design activity provides assessment to how designers' thinking and actions enhance the *Value* of the design process and design results.

The term Lean Thinking (LT) was coined as a result of a research project carried out at Massachusetts Institute of Technology about the automotive industry at Toyota and other Japanese companies. This research, which summarizes the Japanese manufacturing practices, culminated in a product development philosophy (Womack et al., 1990). LT philosophy presents the central concept of *MUDA (waste)* and five principles, namely: *Value, Value Stream, Flow, Pull* and *Perfection* from which *Value* is the most important. This concept set represents a principle-based approach of evolving stages for an effective process. Lean Thinking can be seen as the synthesis of the ancient human need of knowing and doing in an effective way. Lean Thinking philosophy and tools were meant to optimize and control quality, reduce waste, practice low cost and produce shorter time to market cycles. The aim was the creation of *Value* for the ultimate customer through process reliability and the elimination of all forms of waste. LT was seen as a new production paradigm representing a fundamental refocusing in the process of production, with its dual interest on the effectiveness and motivation of the people. The integration of all stakeholders, suppliers, customers and partners as important actors in teamwork was considered from the beginning. Later, Lean Thinking focus became the organizational effectiveness (Womack and Jones, 2005). As the Lean Thinking became accepted worldwide, the main challenge was to generalize Lean practice at organizations everywhere. Given the many dimensions of the tasks involved, lean tools came to the forefront of Lean Thinking extension: 5S, setup reduction, the five whys, target costing, simultaneous and concurrent engineering, value-stream maps, kanban, and kaizen. The period from the early 1990s up to the middle of the 21st century first decade, has been the *Tool Age of the Lean movement* (Womack, 2007). Lean tools were an easy way to improve some aspects that could be managed in isolation, but at the same time it was also a means to avoid tackling the difficult task of changing organizations and rethinking the fundamental approach to management. The Lean Principles original definitions (Womack and Jones, 1996, 2^{nd} ed., 2003) and early transference to product development (Walton, 1999) are transcribed in Table 2.1.

Table 2.1. Lean Principles definition (LT) and transference into product development (PD)

Lean Principles		Definitions
Value	LT	*'Value is a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer.'* (Womack et al., 1996, 2nd ed., *2003, p. 353).*
	PD	*'the right information products delivered at the right time, to downstream processes/customers, where it is quantified by form, fit, function and timeliness of information products.'* (Walton, LAI, 1999, p. 16).
Value stream	LT	*'The specific activities required to design, order, and provide a specific product, from concept to launch, order to delivery, and raw materials into the ends of the customer.'* (Womack et al., 1996, 2nd ed., 2003, p. 353).
	PD	*'The product development value stream consists of tasks that transform information and allow for the convergence of the segmented information to define a final design.'* (McManus, H. (1999). *'The product development value stream is only part of the larger product life-cycle value stream where the customer achieves the desired product value.'* (Walton, LAI, 1999, p. 16).
Flow	LT	*'The progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery, and raw materials into the hands of the customer with no stoppages, scrap, or backflows'* (Womack et al., 1996, 2nd ed., 2003, p. 348).
	PD	*'There is also value which flows to future developments (e.g. human capital preservation and experience, synergies to other products, etc.)'* (Walton, LAI, 1999).
Pull	LT	*'a system of cascading production and delivery instructions from downstream to upstream activities in which nothing is produced by the upstream supplier until the downstream customer signals a need.'* (Womack et al., 1996, 2nd ed., 2003, p. 351).
	PD	*'The following three characteristics are necessary conditions for pull:* *Synchronization (Timing), refers to aligning takt times of interconnected processes such that proper timing is in place, thus enabling flow and allowing for pull to be successful.* *Alignment (Position), describes proper positioning that is necessary for pull to occur. In a manufacturing sense this could mean physical position, in a development point of view, this could mean proper file format and location.* *Transparency describes the ability to see the process totally and without obstruction as a means for identifying problems quickly and efficiently.'* (Walton, LAI, 1999, p. 9).
Perfection	LT	*'complete elimination of muda so that all activities along a value stream create value.'* (Womack et al., 1996, 2nd ed., 2003, p. 350).
	PD	*'Perfection is the continuous improvement aspect of Lean. Understanding that a process today is imperfect and that there is a need for continuous reexamination of the process/product is necessary to remain competitive and lean.'* (Walton, LAI, 1999, p. 10).

Results of tools application showed that LT asks for a systems approach. Progress has been made in implementing and raising LT awareness in several fields of practice and research, and it has been expanded to Lean Product Development (LPD) with contributions on techniques (Karlsson and Åhlström 1996), sub-systems (Morgan and Liker, 2006), principles (Ward, 2007), management domains (Kahn et al., 2006) knowledge domains (León and Farris, 2011), system design framework (Letens et al., 2011) and the Lean Advancement Initiative (LAI) several contributions (Oehmen et al., 2011).

2.2 Translating Lean Principles into Design

Lean Thinking expresses a management approach for the business context where quality, *Flow*, time and cost play an important role in the creation of *Value.* Although LT focuses on the customer and the producer as *Value* creators, designers also play an important role in the collective effort of *Value* definition, especially in the early phases of design and product development. As a philosophy of guiding principles of behavior that has applicability to a large variety of processes, people and organizations (Walton, 1999), Lean Thinking would therefore be transferable to design. Such a task requires a reinterpretation of the original Lean Principles in design. Within this line of exploration, the research proceeds with the reinterpretation in their considered order as follow:

- *Value* from the designers perspective in action and decision-making
- *Value Stream* in design approach across disciplines
- *Flow* in design and decision-making
- *Pull* in design iteration
- *Perfection* in design

For each Lean Principle a description of the original definition is followed by a reinterpretation in design.

According to the original definition, the *Value* principle can '*only be defined* by the *ultimate customer* and it is only *meaningful* when expressed in terms of a specific *product a good or a service* which meets the *customer's needs* at a *specific price* at a *specific time'* ((Womack et al., 2003, p. 16). *The producer creates* and should find a *mechanism* to *rethink the Value* of the product, good or service, from the perspective of the customer with a conscious attempt to accurately define *Value* in terms of the whole.

In design, *Value* cannot be fully defined in the beginning of the process. A distinction needs to be made between the producer and the designer facing the *Value* creation process in the production and design contexts. The producer needs to know the characteristics of the product, good or service for production. There is no design regarding a product, good or service in this phase. The designer's task precedes the task of the producer. The designer materializes the idea into project, the producer materializes the project and both contribute to the *Value* creation process. *Value* creation is also at the core of design activities. The design process is not *Value*-free.

Value analysis method (Miles, 1961) was a label concerned with *Value* in design aiming to increase the rate at which designing and manufacturing organizations could reduce the cost of a product. A systematic approach of four stages was proposed to be applicable, in particular, to the product development of existing products. Each physical component of a product would be submitted to *Value* analysis and approval. The idea of beginning with the market *Value* for each function was a fundamental principle. In spite of the positive effects of *Value* analysis upon tangible variables, the difficulty in estimating the *Value* of intangibles such as appearance became apparent (Jones, 1970). In the last half century research on *Value* made its variables become more tangible for assessment and analysis from different perspectives, sush as consumers' and users'. Thought for designers, *Value* does not necessarily reside in the matter but rather in the message and meaning it communicates that emerges from the experience given to the individuals (Dewey, 1958). Though, for a long time, design methodology kept *Value* away from design.

> *"For my own part, the motive for my entering the field (25 years ago, God help me) was essentially ends-directed, not means-oriented. I was concerned to find ways of ensuring that the predominantly qualitative considerations such as comfort and convenience, ethics and beauty, should be as carefully taken into account and as doggedly defensible under attack as predominantly quantitative such as strength, cost and durability. Moreover, it is demonstrable that the assumptions upon which even the quantitative are based can never be wholly value-free, and I wanted these assumptions to be at least acknowledged in the design process. The study of methods was thus not an end in itself, and was certainly not motivated by the desire to eliminate or down-grade the qualitative considerations, although a lot of people interpreted it that way."*
>
> *Bruce Archer, 1979. Design as a Discipline.* p. 17

In the last decade, design research is bringing *Value* back to design. *Value* seems to play a management role in designers' and developers' perception of the design process and characterizes their design approaches (Enke, 2012).

Value unfolds in many different notions. Although traditionally defined by economic return or a measure of moral standards, *Value* notions span a number of different disciplines such as philosophy, economics, marketing, music and design. Research approaches to *Value* comprises three main dimensions, namely, economic *Value*, human *Value(s)* and *Value* system. In the foundations and development of economic thought and market exchange, two general meanings of economic *Value* were proposed: *Value*-exchange and *Value* in use (Smith 1776). Later, the concept of *Value* was given a more concrete meaning related to common activities, particularly approached in the fields of sociology (Durkheim, 1893) and psychology (Dewey, 1939). A wider notion emerged that each individual creates a personal and flexible hierarchy of *Value(s)* (Allport et al., 1951). Currently, *Value(s)* are seen as guiding principles that rise above in specific situations and may change over time. *Value(s)* guide the selection of information, and steer the behavior and events as parts of a dynamic system with inherent contradictions (Bindé, 2004). *Value* system is regarded as an enduring organization of beliefs concerning preferable modes of conduct or end-states of existence along a continuum of relative importance (Rokeach, 1968). Contributions to research into *Value(s)* unfold in terminal *Value(s)* and instrumental *Value(s)* (Rokeach, 1973) that along with important *Value* components, namely, motivational, cognitive, affective and behavioral, as well as the influence of internal and external features (Rokeach, 1968), guide individuals' conduct and motivate action (Reich, 1976). *Value* notions have a common characteristic: a governing relevance in behavior and decision-making.

Almost 30 years ago, the Action Theory (Argyris et al., 1985) approach proposed a conception of human beings as designers of action under dimensions of analysis that are useful for this research. To see human behavior under the aspect of action was to see it as constituted by the meanings and intentions of agents. Agents design action to achieve intended consequences, and monitor themselves to learn if their actions are effective. They make sense of their environment by constructing meanings to which they attend, and these constructions in turn guide action. In monitoring the effectiveness of action, they also monitor the suitability of their construction of the environment. The spotlight of attention shifts depending on the concerns of agents in particular situations. Governing variables are *Value(s)* that actors seek to satisfy. When one *Value* is not fulfilled the actor takes steps to bring it back to a satisfactory level or rethink *Value* focus. Any action can have an impact on many governing variables. Agents typically must trade off among governing variables because actions that raise the *Value* of one may lower the *Value* of another. Resembling Schön model (1983), action strategies are sequences of moves used by actors in particular situations to satisfy governing variables. Consequences may be intended or unintended, productive or counterproductive. *Value(s)* and strategies may be nested. Action Theory stresses the notion of *Value* as a governing variable of human beings as designers of action.

In design research, emphasis has been placed on *Value* from a user's perspective with user *Value* theories and models (Boztepe, 2007). Few authors have tried to identify *Value* in design (Friedman, 1996, Austin, 2005, MacMillan, 2006;

Langford, 2007) from the designer's point of view. Design researchers have been contributing studies such as mechanisms of *Value* transfer in meetings (Le Dantec and Yi-Luen Do, 2009), affect-in-cognition (Dong et al., 2009), ethical thinking in designing (Lloyd, 2009) and a plural framework for a shared language supporting *Value* management (Prins, 2009). Such studies report results from the analysis of meetings or approaches developed from experience. Although designers play an important role in adding *Value* to products, services and experiences, little attention has been placed on the study of these activities on an empirical base. No transdisciplinary study has been presented on designers' perspectives on *Value* and its implications on decision-making. On the other hand, there is an evolving need to create knowledge on how designers deliver *Value* in design (Heskett, 2008), *Value* influential role in cultural innovation (Jacobs, 2007), design purpose, strategy and focus of people and organizations in innovation processes (Enke, 2012). One definition of '*value in design*' is described as,

> *"The designer or design team makes choices at every point in the design process and most of these are value laden. Every decision at each "choice point" will give priority to certain values over others."*
>
> Timothy Marshall, 2008. *Perspectives on Design Terminology*, p. 434

Value plays an important role in decision-making in design. As a process of thought, design entails the designer making decisions (Akin, 1995), either alone or in collaboration. Decision-making consists of two aspects, whereby the first aspect is to decide upon the own preference and the second is the choice made based on *Value* judgment. Designers' *Value* systems guide individual and collective *Value* judgments about the relative importance of the attributes for a certain result. These judgments most likely derive from stages that support decisions made towards solutions that most reflect designers' priorities (Lera, 1980) in the given context. For the design process to become more public so that '*everyone who is affected by design decisions can foresee what can be done and can influence the choices that are made.*' (Jones, 1970, p. 9), attempts have been made to assess designers' decision-making.

From studies about influential issues to the cognition of designers, such as question asking (Ozgur, 2002), uncertainty (Daalhuizen et al., 2009), decision-making has been acknowledged as a fundamental cognitive mechanism that drives performance. Studies show that most of the designers' time is occupied making routine and novel decisions, therefore it is important to describe the conditions that surround decision points (Akin, 1995). Research in decision-making in design addresses single disciplines such as Engineering design (Wallace, 1995; Badke-Schaub and Gehrlicher, 2003), Architecture (Mackinder and Marvin, 1982; Volker 2008) or Industrial design (Akin, 1995).

Several research issues have been addressed, such as: methods and tools for decision-making (Wallace, 1995); design decisions under uncertainty (Beheshti, 1993; Daalhuizen et al., 2009); context, task and institutional environment of decision-making (Little, 1990); patterns of decision in design (Badke-Schaub, and Gehrlicher, 2003); comparative studies on consensus and single leader decision-making (Yang, 2010); philosophy based models for ethical decision-making in design (D'Anjou, 2010). Transdisciplinary research was not done in more than two disciplines. Influential aspects of decision-making are acknowledged in these studies, such as: experience, use of information from previous projects, intuition, culture, personality, predicted or unforeseen elements of risk, chain of known and unknown design constraints, unknown design variables, interaction of alternative courses of action, validity of design concepts, design intentions, and design *Value(s)* and strategies.

Therefore, this research proposes the empirical study of *Value,* from designers' perspective, in action and decision-making on a transdisciplinary base. Two kinds of theories of action are known: Espoused theory and theory-in-use (Argyris et al., 1985). Espoused theories are those that an individual claims to follow and are often stated in interviews. Theories-in-use are those that can be inferred from action and might become evident in meetings. It is generally acknowledged that what people do is consistent with their theory-in-use, but may be inconsistent with their espoused theories. People often act according to rules that they cannot state. Theories-in-use underline designers' actions and can be made explicit by reflection in interviews and meetings.

In addition, the following activities considered essential to decision-making (Pahl et al., 2007), relate to the Lean Principles, namely: recognizing dependencies, estimating importance and urgency *(Pull),* assure continuity and flexibility *(Flow),* and the assumption that some failures cannot be avoided (*MUDA* is necessary or even essential). Such actions have relevance to this research as dimensions of analysis for the translation of Lean Principles in studying designers' behavior.

According to the original definition of the second principle, *Value Stream is 'the set of all the specific actions required to bring a specific product (whether a good, service or, a combination of the two) through the three critical management tasks of any business – i.e., problem solving, information management and physical transformation task.'* (Womack et al., 2003, p. 19). The practical implementation of *Value Stream* entails a longitudinal perspective of the process. One of the Lean tools for this task is the creation of a map of all the waste (*MUDA)* and identification of specific actions, as an adaptive set of principles to apply in any design process model.

Many researchers tried to identify procedures of action taking place in design. Starting in the 1920's, much effort was done to prescribe and describe the structure (Pahl, 2007), the course of actions (Alexander, 1964), and the frames and moves (Schön, 1988) of the design process. The aim of identifying the actions in the design process was to understand and have more control over the situations. However, the adaptive nature of design methodology to a design project is perceived from the understanding of the problem and its context. This results in a more or less conscious plan of action and indication of a goal and direction to proceed. In its best form it can be part of a design strategic approach, or supported by a structured action procedure.

A distinction needs to be made between process and approach. The word process as a noun means: a series of actions or steps taken in order to achieve a particular end; a natural or involuntary series of changes; a systematic series of mechanized operations that are performed in order to produce or manufacture something. The word process as a verb means: dealing with (someone) using an official and established procedure. The word approach as a noun means: a way of dealing with something; or the action of coming near or nearer to someone or something in distance or time. The word approach as a verb means: start to deal with (something) in a certain way: one must approach the matter with caution (definitions from the New Oxford American Dictionary). Process relates to structured or systematic series of actions to achieve or produce a particular end and deal with people and is susceptible to involuntary changes. Approach relates to a way of dealing with caution with someone or something in distance and time.

Designing implies processes and approaches. *Value Stream* activities such as, *problem solving, information management* and *physical transformation tasks* integrate process and approach in design. With regards to design discipline-related characteristics, the word approach seems to have a better fit concerning the influence of the design background in the way designers design.

The translation of *Value Stream* in design would consider the analysis of the process activities, such as, outsourcing, exchange activities with stakeholders, delivery, product launch, marketing activities, (although, out of scope of this research) and the analysis of design approach. Therefore, the research proposes the empirical study of *Value Stream*, through the analysis of characteristics of design approach across disciplines and identification of the set of actions to cope with *MUDA.*

In the design approach, substantial consideration and effort converge to the formulation of ideas and solutions. Attributes, properties and qualities are specified towards design solutions and results. Complex design problems involve designers from different background disciplines and make them blend and converge design approaches to one purpose. In these situations, different designers share the creative approach and the problem context. Collaborating and sharing the design process and approaches become tasks that ask for management skills, which requires concern with inter-professional collaboration and acquaintance to each other's *Value* judgment criteria. Designers need to '*observe their own thinking in a objective way*' (Jones, 1970, pp xii) and are asked to be aware of the characteristics and dynamic of their own design approaches in a shared design process.

To each background design discipline particular characteristics have a crucial role and influence designers' approaches and actions. This is supported by the concept of object-worlds (Bucciarelli, 2003), the idea that different participants in design see the object of design differently depending upon their education, background, training, competencies, responsibilities and technical interests.

Designers specify attributes, properties and qualities of design solutions and results. Collaborating and sharing the design process and approach became tasks, that ask for management skills. In addition, design involves mental models and a rich set of semantics (Goel and Pirolli, 1992). The materialization of the semantics takes different forms across design disciplines, appropriately qualified as the construction of representations (Visser, 2006). A designer's approach influence the teamwork that, similarly to the individual process, involves a shared perceptual act, a cognitive strategy and in addition, a co-development of problem and solution (Dorst and Cross, 2001).

Therefore, the investigation of the Lean Principles of *Value* and *Value Stream* as dimensions to study designers' behavior asks for multidisciplinary studies across different design disciplines to assess similarities and differences of designers' *Value* concerns and design approach. A comparison is delineated. Designers working in Graphic design say they do not produce Graphic design but objects that happen to be made of paper. Although they create symbols and logos or posters, these are envisioned as three-dimensional, rather than as printed pieces. Paper is seen as an architectonical material, a wall and a window. Interviewees of this research referred to this particular notion, here supported by a well-know designer: '*I perceived paper as a mass contained between two facades.*' (Ambasz, 1988, p. 296). Industrial designers are particularly focused on ergonomic concerns and the function and overall configuration of a product design. Architects aim to: '*provide new and advanced standards of living for all peoples of the world.*' (Fuller, 1983, p. 239). All-purpose designers aim to: '*Sometimes, I confess, I fancy myself to be the last man of the present culture, building a house for the first man of a culture that has not yet arrived.*' (Ambasz, 1988, p. 29). Claims are made that engineers need to see the world differently and change the reductive and instrumental character of the engineering thought and practice (Bucciarelli, 2003). However, to be an engineer at any time between 1850 and 1950 was to be a participant in a great adventure: '*Technology, as everyone could see, was making miraculous advances, and, as a natural consequence, the prospects of mankind were becoming increasingly bright.*' (Florman, 1976, p. 4). The Engineering profession went through similar thoughts that some designers have nowadays: '*What was new about engineers as they started to develop as a profession was the delight they took in thinking of themselves as saviors of mankind.*' (Florman, 1976, p. 6). Not just on the individual level but also on what they expect from the society, '*Once the common man was released from drudgery, the engineers reasoned, he would inevitably become educated, cultural and ennobled, and this improvement in the race would also be to the credit of the engineering profession.*' (Florman, 1976, p. 6). At that time, engineers felt they were improving the world with their activities but also by their "*way of thinking*".

Mogens Myrup Andreasen made a distinction between Engineering design and Industrial design methods (lecture at *Food for thought*, Delft, 11th of April 2011). Engineering methods: analytical, calculations, variables, optimization; Design methods: synthesis, clarification, based upon a staging, and industrial designers structure the research, discussions, evaluation and decisions. Engineering design approach is hierarchical and mathematical, based on scientific theory, concepts, principles, cause and effect of particular phenomena, measurement, estimation and certainty. Reduction is essential to engineering thought. However, '*It fails to acknowledge that designing is a social process of negotiation, of iteration, of rectifying mis-steps, even misconceptions - a process rich in ambiguity and uncertainty.*' (Bucciarelli, 2003, p. 7).

Architecture also went through a similar process with the modernist attempts to standardize the living environments. Despite the beauty of some results, modernist purposes as the mechanization of engineering were understood as if history and expression were being ignored or less important in understanding technology.

Knowing that socially desirable answers can obscure the validity of research, this thesis aims to identify what really drives designers to cradle and prioritize *Value* in design. This research aims to identify what do designers *Value* in real life design environments.

Context plays an important and relevant role in many design disciplines and design approaches. Designers take many ways of reading and perceiving the world framed by standard, traditional, new, fashionable and dynamic *Value* assumptions. Design situations can vary significantly requiring different creative approaches. The core of a creative approach lies in the ability to mold experiences into new and different organizations and to communicate the resulting experience to others (Taylor, 1959). This process is characterized as a communicative task of transforming implicit experiences into objective symbolic form and additional skills in translating subjective notions into objective form.

To completely specify solutions, designers need to characterize elements and attribute qualities that give substance to their mental representations resulting in tangible or intangible artifacts, as the feelings provided by a design experience. Studies with relevance for design demonstrate that the factors governing the visual perception (Metzger, 1936) are inherent to each one visual system and the organization of the visual field occurs essentially without our involvement. These rules hold that stimuli organize themselves in the simplest and most balanced manner, complemented by a set of perceptual constancy or invariants that enable us to recognize objects and form experiences for what designers have increased sensibility.

The characteristics of the design approach also depend on the set of design elements and tools used in daily work. Working more commonly with design elements such as abstract representations such as alphanumeric, or schematic representations of mechanisms and structures, can lead to more abstract concerns of structural relation. Meanwhile more vivid mental models of accurate representations of final appearance, allow the designer to characterize the solution in a closer approach to the final result, framing the *Value* assessment of what will become physical artifacts and its intangible results (Visser, 2009).

The third Lean Principle, *Flow* is originally defined in relation to *Value* as '*making the remaining, value-creating steps flow*' (Womack et al., 2003, p. 20) with the function *to channel the flow of value from concept to launch. Flow*, in manufacturing means *Flow* of goals and parts. Lean thinking presents two ways to achieve continuous *Flow*: *kaikaku*, for radical improvement and *kaizen*, for continuous incremental improvement. The definition of *Flow* also includes the psychological *Flow* of the people while working (Csikszentmihalyi's, 1990, 1996, 1997), which explores what makes people feel good so that positive attributes of experience can be built into daily life, the creative processes and engagement. Findings report on the conditions that people consistently refer to as most rewarding, namely: *involve a clear objective; a need for concentration so intense that no attention is dismissed; a lack of interruptions and distractions; clear and immediate feedback on progress toward the objective; a sense of challenge; the perception that one's skills are adequate to cope with the task at hand* (Womack et al., 2003, p. 65).

However, *Flow* in design is more complex. The progressive achievement of tasks along the set of actions (*Value stream*) is not straightforward but entails many aspects that influence the process. Sto*ppages, craps* or *backflows* have a role in design (Badke-Schaub and Gehrlicher, 2003). They lead to iteration processes of reviewing and re-doing, even if some waste *(MUDA)* or some *Value* loss is found in these actions. Optimal conditions of *Flow* in design provide a chain, a matching process (von der Weth, 1999) or a good fit (Alexander, 1964) along with the perception of control. This chain of *Flow* is attained through many valuations and decisions. Some non-decisions or even breaks are occasionally essential too. In addition, teamwork is also a factor of influence on individual and collective *Flow*. The early transference of the *Flow* principle (Table 1.1) to product development entails a characteristic shared by designers, which is the identification of *Value*, which *Flow*s to future developments.

Therefore, the research proposes the empirical study of *Flow* through the analysis of *Flow* breaks, stoppages and conditions, as well as *Flow* drivers in designers' reports and action, such as, *Value* judgment - defined as the assessment of something in terms of one's standards or priorities (definitions from the New Oxford American Dictionary). This asks for studies across disciplines and the identification of *MUDA* in situations of *Flow* stops, breaks and conditions.

The fourth Lean Principle, *Pull*, was originally defined as '*a system of cascading production and delivery instructions from downstream to upstream activities in which nothing is produced by the upstream supplier until the downstream customer signals a need*' (Womack et al, 2003, p. 351). This means that someone upstream should not produce a good or service until the customer downstream asks for it. Each activity pulls the next, they *Flow* only when *Pulled* by the following step.

By definition, *Pull* means to exert force on (someone or something), typically by taking hold of them, in order to move or try to move them toward oneself or the origin of the force; or take hold of and exert force on (something) so as to move it from a specified position or in a specified direction (definitions from the New Oxford American Dictionary).

Pull in design relates to needs, demands, imperatives, a clue or an indicator within an activation function of the next actions. Known and unknown variables and interdependency of design issues are brought into *Value* Judgment in order to reduce uncertainty. On a macro-level '*fundamental issues and processes involved in designing are not uniquely related to any particular design task, designer or design situation*' (Gero, 2010, p. 188). On a micro-level, design issues are specifically related to the design subject context. Unknown variables of Design issues *Pull* the process with the recognition of the right moment to proceed and an intense effort to focus on the required issue and coping actions. The demand of the design problem assignment is *Pull* in itself. *Pull* entails recursiveness and iteration in design (Roozenburg and Cross, 1991) and priority of *Value* (Lera, 1981). The necessary conditions for *Pull*, *Synchronization (Timing), Alignment (Position)* and *Transparency* can be seen as challenges that also in design, enable *Flow* allowing *Pull* to be successful. Therefore, the research proposes the empirical study of *Pull*, through the analysis of priority, iteration and interdependency processes of design issues and the identification of the sources of *MUDA* in situations of *Pull,* what is missing, what can be waste or *Value* loss and activation of next actions in iteration processes.

Perfection, the fifth Lean principle was originally defined as the '*complete elimination of MUDA so that all activities along a value stream create value*' (Womack, 2003, p. 350). The previously described four Lean Principles are aimed to interact with each other in a virtuous circle to improve transparency and effectively pursue both radical and incremental improvement. Perfection is unattainable but also a regular concern for humans. In design, perfection can be understood as the most favorable plan of action or strategy to successfully achieve a solution, eliminating the superfluous aspects along its course.

This thesis proposes the investigation of Lean Principles speculating about its usefulness, translation form and elements of effective behavior in design. Taking a Lean perspective in design research might bring these aspects into evidence, sources of *MUDA* and coping actions.

2.3 Translating *MUDA* into Design

As previously mentioned, the Lean concept of *MUDA* (waste) is defined as '*specifically any human activity, which absorbs resources but creates no value*' (Womack et al., 2003, p. 355). The first seven types of *MUDA* (Ohno, 1988) were identified in the context of physical production, namely: *defects, overproduction, inventory, movement, transport, waiting* and *over processing* and then further extended (Womack et al., 2003) to nine types to include: *useless* and *complexity*. Therefore Lean Thinking was asserted as an antidote for *MUDA* in the sense that:

- Provides a way to specify *Value.*
- Line-up *Value* creating actions in the best sequence.
- Conduct these activities without interruption whenever someone requests them.
- Perform them more and more effectively.
- Channel the *Flow* of *Value* from concept to launch.

Two other similar concepts were proposed, *Mura* and *Muri* (Morgan and Liker, 2006). However, the definitions of the 3 M's constitute an organized set that was thought it would have framed too much their translation in design. Therefore, this research took the most general concept of *MUDA*, which translation in design was expected to bring new perspectives and a differently structured set.

In a first approach to the objectives of this research, *MUDA* in design was comparable to the sources of fruitless behavior. From the literature in design research few attempts provide understanding of less successful designers' performance. From the literature, contributions focus on downside aspects of specific issues such as stuckness (Sachs, 1999), inappropriate focus of attention (Simon, 1995) and confirmation bias (Wason, 1960).

However, one might think that *MUDA (waste)* among others that the reader might identify - for example, the need to review or redraw - are also essential to further the design process. Indeed many among designers would make sense of *MUDA*, justifying and probably confirming its role in the evolving conjecture of the design process. Attributing an underlying sustainable concern to the identification of *MUDA* would not sound unwise based on the idea of an effective management of resources. We might need *MUDA* in design.

Lean Thinking proposes to convert *MUDA (waste)* into *Value* (Womack, 2003, p.15) as opposed to completely avoiding *MUDA*. Thus, reviewing, redrawing and other re-processes of iteration are not excluded from the Lean Thinking Philosophy. In addition, *MUDA* can also be translated into design as *Value* loss, sometimes necessary other times recognized. Thinking of design in terms of *MUDA* might provide a control function supporting the designer focal awareness on the holistic level of the problem situation while keeping him/her aware of the particulars along the course (Polanyi, 1958). Therefore, the research proposes the empirical study of *MUDA* in designers' discourse and action, how designers recognize *MUDA*, causes, antecedents, consequences and what coping actions are taken. From a preliminary analysis of data, *MUDA* types were recognized in the design activity. Although several Lean Thinking types of *MUDA* are specifically and explicitly speaking to physical constructs, they also seem to have a parallel translation to designers' difficulties felt in cognitive dimensions and in decision-making. Examples are described:

- *MUDA of transport -* in the process, due to communication issues in gathering information from the clients; in cognition, due to misinterpretation or difficulty to transport imagination.
- *MUDA of movement -* in the thinking process due to interruptions.
- MUDA of over production - in the course of time due to work overload; in cognition such as difficulty to think in the future due to pressure.
- *MUDA of waiting -* in process delaying due to not receive information on time, or team dependency on office's leader inputs and decisions.
- *MUDA of complexity* – in the process due, to specific context circumstances; in cognition, such as uneasy problem perception; in decision making, due to non-convergent opinion or client's complex structure of decision.
- MUDA *of defects -* in cognition, feeling stuckness or obsession for creating solutions; in the process, such as defects in execution.

- *MUDA of transport* - in the process, due to communication issues in gathering information from the clients.
- *MUDA of over processing* - due to change of projects information content.

Analogy between *"movement of people from one place to another"* and *"Difficulty of keeping focus of attention"* brought into evidence consequent effects between *MUDA* types. General meanings found for the translation of each type of *MUDA*, were later unfolded in sub-dimensions of analysis, such as temporal and process implications.

A preliminary translation of the original *MUDA* types in design is depicted in Table 2.2. As the research evolved, this mapping became inaccurate, overlapping between categories and new aspects and dimensions of analysis, such as the cognitive dimensions, lead to the extension of the notion of *MUDA* in design, further describes in chapter 5.

Table 2.2. Preliminary translation of *MUDA* in design (from the *MUDA* types, Womack et al., 1996, 2nd ed. 2003)

MUDA	Translation	Categories	Behavioral examples
Defects	*LT definition*	*In products (p.355) mistakes that require rectification (p.15)*	
	In design	Situations where designers are unable to continue, due to mind overload, missing or disregarding information.	
		Cognition	Stuckness (Sachs, 1999)
		Process	Missing criteria in problem formulation
			Not regarding constraints, patents, rules
Over production	*LT definition*	*Production of goods not needed (p. 355) production of items no one wants (p.15)*	
	In design	*Situations where designers attach to unreliable planning, produce unnecessary results or find themselves overloaded by information.*	
		Cognition	Overestimation of predictability
			Difficulty to think in the future
Over processing	*LT definition*	Unnecessary processing (p. 355) processing steps which are not actually needed (p.15)	
	In design	Situations where designers do not well-frame anticipation, thought, analysis and ideation space.	
		Cognition	Anticipation without regarding the context
			Wishful thinking instead of thorough analysis

		Process	Small search area for solutions
			Anticipation without demand
Movement	*LT definition*	*Unnecessary movement of people (p. 355) movement of employees from one place to another without any purpose (p.15)*	
	In design	Situations where designers have difficulties in transfering information, keeping focused, think differently, are dependent on others and interference makes them change their mind-set.	
		Cognition	Communication: problems of information transfer
			Difficulty keeping focus of attention (Simon, 1995)
		Decision-making	Dependency on others, such as the absence of someone, without whom a decision cannot be made.
Waiting	*LT definition*	*By employees for process equipment to finish its work or on an upstream activity (p.355); groups of people in a downstream activity standing around waiting because an upstream activity has not delivered on time.(p. 15)*	
	In design	Situations where designers have difficulties to continue, due to pressure or inability, delays and dependency from others or from resources.	
		Cognition	Difficulty to think under pressure
		Process	Delays provoked by the client, deliverer etc.
			Dependency on others, client, on resources
		Decision-making	No decisions: missing feeling of competence.
Transport	*LT definition*	*Unnecessary transport of goods (p. 355); Movement of goods without any purpose.(p. 15)*	
	In design	Situations where designers have difficulties to transport imagination, generating alternatives or to convey transparent information transfer.	
		Cognition	Difficulty to think differently; Non generating alternatives
			Difficulty to transport imagination
		Process	Communication: problems of information transfer (transparency); confirmation bias (Wason, 1960)
Useless	*LT definition*	*The design of goods and services that do not meet the needs of the users* (p.355).	
	In design	Situations where designers do not match the design problem, client or user needs.	
		Cognition	Bounded rationality (Simon,
		Process	Do not match customer needs
Inventory	*LT definition*	*Goods waiting further processing or consumption (p.355). Remaindered goods pile up (p.15)*	
	In design	Situations where designers do not keep/or have to keep excessive record of the design process.	

		Process	Documentation: not keeping record of sub-results
Complexity	*LT definition*	*When managers fail to grasp the cost of maintaining and coordinating a complicated network of high-speed machines making batches* (p.60)	
	In design	Situations where designers have difficulties to grasp a problem, to cope with stakeholders and to choose a path to follow.	
		Cognition	Difficulty to grasp the features of a problem
			Memory overload
		Process	Clients do not know what they want
		Decision-making	Difficulty to choose a path to follow

2.4 Variants and Invariants of Behavior in Design

'The fundamental goal of science is to find invariants, such as conservation of mass and energy and the speed of light in physics. In much of science the invariants are not as general or as "invariants" as these classical laws.'

Herbert Simon, 1990. *Invariants of Human Behavior*, p. 1-2

In pursuing and sharing aspirations for a Design Science[1], this thesis attempts to contribute to design research with the understanding of design taking the lens of Lean Principles and *MUDA* and contribute with knowledge about designers' behavior across disciplines. Attempts are possible through the identification of variants and invariants of design (Akin, 2001; Visser, 2009). When compared to the classical models, invariants are difficult to assess, its accomplishment must derive from how well such invariants describe and explain successful human behavior, assumption that can be extended to design (Simon, 1990).

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[1] Nigel Cross (2000, p 96) defines *Design Science* as 'an explicitly organized, rational and wholly systematic approach to design; not just the utilization of scientific knowledge of artifacts, but design in some sense a scientific activity itself' and makes a distinction from *Science of Design* (Simon, 1969) as 'the body of work which attempts to improve our understanding of design through 'scientific' (i.e., systematic and reliable) methods of investigation'.

'In biological (including human) realms, systems change adaptively over time. Simple change is not the problem, for Newton showed how we can write invariant laws as differential equations that describe the eternal movements of the heavens. But with adaptative change, which is as much governed by a system's environment as by its internal constitution, it becomes more difficult to identify true invariants.'

Herbert Simon, 1990. *Invariants of Human Behavior,* 1990, p. 2

This research attemps to study designers' successful behavior in situations of potential waste *(MUDA) therefore, Value* loss. Designers, as adaptive systems in adaptive change, have a twofold nature of the governing variables: exogenous, relating to, or developing from external factors; or endogenous, having an internal cause or origin. Both can be under mutual influence. The analysis of sources of *MUDA* must regard both, internal and external causes in designers' behavior. *Value* judgment and decision-making are invariants of behavior that play a crucial and interdependent role in design as a social and individual process (Lera, 1981). Variance relates to how cultural predisposition colors thought (Douglas, 1996), background, activity and characteristics of the design approach. These dimensions of analysis are relevant for this research.

2.5 Research Question

The review of the literature in design research and the theoretical background on the translation of Lean principles and *MUDA* in design provided support to the idea that this thesis should not strive for a direct application of Lean Thinking in design but that LT can be useful in understanding and explaining designers thinking and acting across design disciplines. The purpose of this research is to attempt the translation of the LT into design, primarily based on the identification of the Lean Principles and the concept of *MUDA* in designers' behavior. By definition, behavior means the way in which one acts or conducts oneself, toward others or in response to a particular situation or stimulus (New Oxford American

Dictionary). This thesis investigates how far *Value* plays a role in designers' conduct and actions (*Value Stream*) taken in *MUDA* circumstances, intertwined with *Flow* conditions, requests and priority (*Pull*), and how far these elements determine effectiveness of designers' performance. The dimensions of analysis derived from the preliminary understanding of Lean Principles and *MUDA* in design provided ground for the development of the research as guidelines for the research question and sub-questions (Table 2.3). Studies are explained in Chapter 3.

Table 2.3. Dimensions of analysis from the Lean principles (LP) translation and sub-research-questions

Lean Principle	Dimensions of Analysis	Research sub-questions
Value	Identify *Value* from designers' perspective	*What do designers' Value while designing across different design disciplines?*
	Identify how designers deliver *Value* in action	*How do designers deliver Value to the design process and design results in design meetings?*
Value Stream	Identify characteristics of designers' approach	*Do designers sharing the same design environment show the same design approach characteristics?*
	Mapping *MUDA* in design	*How to map MUDA in design across different design disciplines?*
Flow	Identify *Flow* circumstances	*What are designers' Flow characteristics?*
	Identify *Flow* sequences in interaction	*How do designers deliver Value to the design process and design results in design meetings?*
Flow and Pull	What do designers *Value* and prioritize in decision-making	*Which invariant characteristics across different design disciplines can be found in decision-making?*
	Interdependency and Iteration of design issues	*How do instances of Value judgment evolve in design meetings across design disciplines?*
MUDA	Identify *MUDA* in designers' discourse	*What situations of MUDA can be found in design across disciplines?*
	Identify *MUDA* in designers' discourse and action	*How far situations of MUDA share invariant characteristics across design disciplines?*
LP and MUDA	How do designers seize coping actions to cope with *MUDA* situations	*How do designers prioritize Value in actions to cope with MUDA situations in design across design disciplines?*

Some preliminary answers to the research sub-questions are set as proto-hypotheses:

- In design, the *Value* principle differs from the manufacturing context.
- The situations of *MUDA* differ from those of the manufacturing context.
- *MUDA* is an essential part of the design process.
- Lean Principles are intrinsic to designers' effective behavior.
- Designers are Lean Thinking enablers.
- Designers might do not know and not be trained for coping with *MUDA* in design in an effective way for an effective *Value* definition.

A case study based approach in five design disciplines, further explained in Chapter 3 and 4, gives ground to the exploratory research of the Lean Principles in design aiming to answer the main research question:

> *How can Lean principles contribute to the knowledge of the design process and designers' behavior across different design disciplines?*

Chapter 3 describes the research approach, philosophical stance, selected research methods, the selection of the case studies, assessment of research objectives, researcher role and intervention, data collection, data processing, coding and clustering procedures, data analysis, cross-case analysis, overview of the studies and research sub-questions.

3 Research Methods

In the philosophy of science two dominant scientific belief systems are distinguished: the Positivism, a traditional view on science within technology and the natural sciences; and the Constructivism, that emerged from the social sciences in the second half of the previous century (Sullivan, 2001). Design research was primarily conducted within the frames of the positivist paradigm but more research has been performed on the basis of the constructivist paradigm (Reymen, 2001). Two dominant paradigms for describing design (Dorst, 1997) have prevailed, namely, the Rational Problem-Solving (Simon, 1969) and the Reflective Practice (Schön, 1983) that describes design as a reflection in action and presents a pattern or mechanism of designing. Different approaches evolved from these two streams, such as the Complex Problem-Solving (CPS). In Europe the CPS research (Berry and Broadbent, 1995; Dörner and Wearing, 1995) was based on computer-simulated problems of high complexity. In North America, researchers investigated problem solving in different knowledge domains. Since then the increased interest to study design in contextual environments has been acknowledged as an important aspect of research in design.

The research methodology underlying this thesis initially took two of these philosophical streams, namely, the Reflective Practice, the closer approach to the learning-by-doing nature of designing as a thinking and acting process, and the Complex Problem Solving approach in contextual design environments, a more systematic approach to guide the observations derived from these two lenses. Blending the two perspectives was considered the appropriated outline to understanding design in real life design environments from a Lean Thinking perspective.

Later, the topic of *Value* gained importance in this research in a way that somehow seemed to touch one of the streams taken by the Philosophy of Technology after the Empirical Turn (Achterhuis, 2001). Assessing *Value* became a need to study design on an empirical base, as a process whose results have technological effects on the human condition. Although such an approach had focus in Engineering design, some general perspectives on the Philosophy of Technology heeds everything of *Value* and its role in social issues and problems (Dusek, 2006) that similarly to design environments, play a decisive role in design management and decision-making.

Qualitative research (Silverman, 2005, 2009) has been associated over the years with the proponents of the contextual approach arguing that qualitative and contextual approaches offer access to valuable type of data and a deeper and richer understanding of human behavior (Sullivan, 2001). From the ecological metaphor (Bronfenbrenner, 1979; Barker, 1968), behaviors emerge in environments that are a consequence of conditions outside the narrow ambit of the individual assumption. Behavior settings, including design offices, have both static and dynamic attributes, standing patterns of behavior, and the interpersonal relationships among people. The synomorphs (Barker, 1968), the setting in which this interaction occurs, is the background in which observation and data collection was made in this research.

Observing people in their working environment provides access to aspects, such as contextual influence in design as a social activity that cannot be acquired with other techniques such as lab experiments. The qualitative approach in design research stresses the idea that knowledge best emerges when researchers understand the full context in which designers behave and the meanings that people attach to themselves and to what they do (Cross et al., 1996; McDonnell et al., 2009). Therefore the research approach is:

- **Empirical** - based on the direct observation of the world - to see if the Lean Thinking perspective has ground to settle a connection with the facts observed in design - in communities of practice, for what case studies emerged as the appropriate method.
- **Explanatory** – aims at determining why or how situations of *MUDA* and LT principles occur in designing. Attempts to find the causes of the phenomenon and strives to develop explanatory systems.
- **Qualitative** - involves the analysis of data in the form of words, pictures, descriptions or narratives.
- **Quantitative** - uses numbers, counts, frequencies, comparisons and opposite measures to draw conclusions.
- **Exploratory in nature** -The research is descriptive, resulting in the development of concepts and frameworks rather than its verification.

3.1 Case Study Method

> *"The quality of a case study depends less on ideas of sample, validity and reliability and more on the conception, construction and conduct of the study. It depends on your initial idea, the ways that you choose your case, the thoroughness with which you describe its context, the care you devote to selecting appropriate methods of analysis and the nature of the arguments you deploy in drawing your conclusions."*
>
> Gary Thomas, 2011. *How to do your Case Study*, p. 71

For the purpose of this research, the case study method does not intend to be a monographic approach in the tradition of the French sociology, but a method instead. Case study is an in-depth and descriptive study of the context, actors, processes and meanings with the purpose of explanation (Thomas, 2011). The case study method is about seeing the research problem in its completeness from many angles, investigating contemporary events within its real-life context (Yin, 2009). In the past, generalizations from case studies were not easily acknowledged. However, many are the contributions based on the researchers ability to draw from experience and put things together that lead to informed judgments about cause and effect. In the tradition of the Chicago School, the first important forum for qualitative methodology in sociology, the case study method was the choice to identify social problems provoked by urbanization and immigration and how its ecological resources were integrated (Hamel et al., 1993). Taking the analogy, this research attempts to identify *MUDA* (waste or *Value* loss) in the design context, as potential problems of the design activity provoked by the social context, structure and complexity of design offices and how the underlying concerns of designers actions, comparable to LT principles, integrate the means, meanings and resources. The case study is the appropriate method to assessing causes, consequences, why and how of people's purposes for the explanation of phenomena, as important aspects of the teleology, the doctrine of design and purpose in the material world.

In this research the case study method is based on periods of observation for the analysis of persons, projects, events, decisions, studied holistically and in detail by one or more methods of analysis. From these progressive studies, instances of classes of phenomena provided analytical frames and guidelines to conduct the research to categorization systems, illuminating the explanations on how to integrate the complementary results in a whole picture of an integrative framework. A distinction was draw between multiple case studies and what is called "embedded"(Yin, 2009) or "nested"(Thomas, 2011) case studies, which are a subunit within a larger unit of analysis. This research entails multiple and nested case studies selected to compare clearly different examples, jointly studied to investigate the concept set of Lean Principles and the phenomenon of *MUDA* as dimensions of designers' behavior, as the principal unit of analysis.

3.2 Case Studies Selection

Case studies provide a research environment propitious to gathering practical, concrete and context-dependent knowledge essential to gain insight into causal mechanisms and contextual considerations (Flyvbjerg, 2004). The careful selection of representative and instrumental case studies (Silverman, 2005) is the most critical decision in the analytic process (Hamel et al., 1993). A variation in case selection can lead to obtaining information about the significance of various circumstances in the design processes, and their similarities and differences. Case studies provide reliable and representative information about the broader classes of designers and offer useful variation through the selection of deviant cases to complement data and refine results.

The case studies selection was focused on design disciplines, which design processes, go through stages of materialization of ideas with tangible and intangible effects. Selection was also based on design disciplines that the researcher felt comfortable to investigate, in knowing the shared language, terminology, cultural characteristics of the community of practice and its relevance in the design approaches. The research adopted five case studies representative of design disciplines that could also have a revelatory character (Thomas, 2011). The five case studies are based in four design consultancies established in the following design disciplines: Graphic design, Architecture, Interaction design, Mechanical engineering and one group of Industrial design graduating students. Other criteria was based on the identification of trustworthy design consultancies known for their reputations, with an organizational structure of 10 people average, led by design experts, where behavioral patterns could be derived from examples of competent performance. Context-dependent knowledge and experience are at the very heart of expert activity (Flyvbjerg, 2004). The well-known experts' ability to arrive at problem diagnoses and solutions rapidly and intuitively was a central criterion for the selection of design consultancies (Dreyfus and Dreyfus, 1986). Other criteria for the selection of design consultancies was to choose design environments where people enjoyed and felt engaged with their work, and therefore had the free choice and freedom to speak so that their reports are honest. Fulfilling these criteria, the validity of inquiry in the action context was not threatened by defensive routines of self-censorship and face saving. The selection of the design disciplines was as follows:

Graphic design - for being an underlying subject of all the design activities, fast design processes, variant content of its design briefs, easy reproducibility, distribution and diffusion in society. For being a classic design discipline, particularly based on semiotics and communication, stable in its knowledge and processes, therefore an almost independent activity.

Interaction design - for being an emergent design discipline, of complex design processes, involving designers from several backgrounds and the assimilation of management tasks. For exploring and adopting the results of technological artisan, embryonic processes of reproducibility, undeveloped knowledge or knowledge that does not yet exists in a stable and organized structure and for being an area that brings new and specific design issues.

Architecture - for being a classic design discipline that manages the integration of the arts of several design disciplines, for having long design processes, long-term achievement of results and less straightforward reproducibility. For being socially representative and having a special focus on authorship and permanence of results, demanding social reliability, stable knowledge and constant aim to improve people's life quality.

Mechanical Engineering - for being a classic design discipline, fundamental to society and critical to many design activities, for its regulatory nature but also unending aim for discovery, association of science and technology evolution, complex design processes, social reliability, specific methods and design issues, and for the controversy around its aim to simplify people's life.

Industrial design - for extending the engineering role in the task of blending science, technology and art. For the mass reproducibility, variant content of design briefs, direct concern with the users, usability, social utility and aim to provide better and pleasant experiences. For having multifaceted and sometimes long design processes with connections to many other areas of knowledge.

The design consultancies based on Graphic, Interaction design and Architecture are active in the business environment. The design consultancy based on Mechanical engineering operates in the academic context for academic and business environments. The fifth case study is a graduation project of students in Industrial design engineering. This case was seen as a revelatory case study that would tell us how far students are aware and prepared to cope with *MUDA* in designing. The researcher made the contacts and presented the case study proposal to the leaders of the design consultancies to negotiate the conditions of the cooperation, confidentiality issues and informed consent. The observation of the case studies in Graphic design, Interaction design and Architecture was conducted in Portugal and the case studies in Mechanical engineering and Industrial design were conducted in the Netherlands. In Chapter 4, a description of each case study is provided in more detail.

3.3 Researcher Role and Intervention

The researcher role and intervention were based on the techniques of participant observation and interviewing. The Ph.D. candidate has background and working experience in Architecture and Industrial Design, which involved interactions with several engineering disciplines. The experience of working in R&D projects in an academic environment gave the researcher a different perspective of the Mechanical engineering and Industrial design worlds. Such practice provided the development of competencies based on a shared understanding of the case studies communities to better comprehend designers' behavior and verbalization of their mental and physical actions. Being an insider with a grasp of the communities' languages does not fully prevent misinterpretation. In designing, one single action can derive from a network of reasons and be performed in many ways. Another aspect of the problem of interpretation is that designers may either conceal some of the intentions and *Value(s)* of their actions or may be simply unaware of it. Therefore, the researcher was focused on the analysis of utterances of evident and logical reasoning. The actors in the case studies were asked to think aloud (Ericsson and Simon, 1993) and verbalize their thoughts and explanations as much as possible.

Case study also requires an understanding of the meanings designers assigned to their own patterns. Such observation should be present in the context of designing so that the observer gradually becomes integrated and in close contact with key informants. The first step in the ladder of inference in interpretation relates to the audio and video recording of data for transcription and iterative analysis. The researcher kept silent in meetings, however, few interventions were made to clarify doubts to better understand and follow people's reasoning and argumentation, without loosing the focus. Secondly, the cultural meaning of the utterances was many times reviewed according to each design discipline, to the particular characteristics of each design consultancy, and to the profile of each designer, and doubts were clarified with them in appropriate occasions. The third step of the ladder of inference was to be able to keep a careful control over the meaning sometimes instinctively imposed by the researcher as a consequence of being fully emerged in data coding and analysis. This was the most critical step each time a study had to be performed and demands a lot of mental effort and concentration to keep the same resolution level of the analysis. It was very important to keep definitions, examples, explanations and criteria in mind to clearly code the transcripts, cluster the codes and categorization tasks.

As the researcher and Ph.D. candidate of this thesis, I identified and made the contacts for all the design consultancies and students for data collection, conducted all the interviews, was present in all the meetings and performed the audio and video recordings. I transcribed all the selected interviews and pieces of meetings for analysis. The selected interviews answered in Portuguese were transcribed and then translated to English by a professional. All the selected interviews were sent to the interviewees for approval. Regular meetings were held with the supervisors of this doctoral thesis to recall the importance of reducing bias, strengthen the construction of the explanation and to keep the resolution level of the analysis in consonance with the research objectives and long-term vision (Phillips and Pugh, 2006). A single case studies investigator, the Ph.D. candidate, conducted the empirical studies. Feedback has been provided to each design consultancy regarding the studies published in conferences, as well as for this piece of manuscript.

3.4 Data Collection

The researcher adopted the following sources of evidence for data collection methods and construct validity, namely: observations of meetings of selected projects and office daily life; interviews of the organizational team members; design research diary to document the researcher activities and notes of situations of interest; audio recording of interviews and short moments of discussion; audio and video recording of meetings; and visual documentation of results from the design processes. Data were collected in design environments during continuous periods of observation providing insights into designers' behavior. Data used in this thesis are based on the observation and analysis of sequential meetings of on-going projects, interviews, and visual documentation supported by research diary notes as illustrated in Table 3.1. Data were sequentially collected per case study with data analysis and studies accomplished in between over a period of two years.

Table 3.1. Overview of meetings and interviews per case during the periods of observation

Source of data	Case Study 1	Case Study 2	Case Study 3	Case Study 4	Case Study 5	Total
	Graphic	Interaction	Architecture	Engineering	Industrial	
Interviews	9	23	9	9	5	55
Meetings	6	7	7	8	-	28
Visual Documents	Sketches Mock-ups Drawings Mails	Sketches Mock-ups Drawings	Sketches Mock-ups Drawings	Sketches Drawings Building-prototype	Design reports	
Observation	6 weeks	4 weeks	5 weeks	5 month	14 weeks	11 month

Meetings of the case studies in Graphic design, Architecture and Mechanical Engineering were audio and video recorded in three sets of six, seven and eight sequential meetings, respectively. The meetings of the Interaction design case study were not recorded due to confidentiality issues. However, the meetings were handwritten in the research diary with focus on the identification of situations of *MUDA*. Other sources of evidence are the audio and video recordings, mails exchange, observations kept in the diary and in memory that many times helped to understand the context and meaning of the transcripts. The five years recall process conducted to associative reasoning, pattern matching and cross case axial coding.

Observation Focus

In this research the most important form of designers mental and physical action is speech, which can be recorded, and with some loss of information, transcribed. The separation of speech from action that the transcripts provided was compensated with audio and video recordings to assess the mood, context, the objects and matters of conversation and meaning of the utterances. These methods supported the observation and analysis of designers' verbalizations when they performed actions such as arguing, justifying, wondering, negotiating, delaying or avoiding some negative steps or promoting positive ones. *Value* assessment, *Flow* conditions, breaks and *Pull* inputs occur in such circumstances and can therefore be connected to the Lean Principles from a design perspective.

Interviews

One half-structured interview was elaborated in two stages, a first draft including predefined open questions applied in a pilot case, from which in a second stage, the same number of topics were unfolded in groups of questions. Open questions gives the interviewees the chance to develop their thoughts and discourse about the topics, sometimes leading to very informative and rich moments of conversation. Details about the interviewees' background and activity are shown in Table 3.2.

Table 3.2. Background and activity of the subjects of the selected interviews

Background	Activity	Interview	Length	Case Study
Graphic design	Leading designer	Int1	1:11:46	Cs1
	Producer	Int2	59:07	Cs1
	Graphic designer	Int3	55:41	Cs1
	Editorial designer	Int4	52:29	Cs1
	Graphic designer	Int5	1:10:25	Cs1
	Leader/Art Director	Int1	1:26:27	Cs2
	Experience designer	Int3	1:39:30	Cs2
	Illustrator	Int4	1:42:39	Cs2
	Leading designer	Int5	1:41:43	Cs2
Multimedia design	Interaction designer	Int2	2:00:11	Cs2
Social Communication	Producer	Int6	1:18:47	Cs1
Literature	Copy writer	Int10	1:22:58	Cs2
Software Architecture	Software Architect	Int9	0:53:30	Cs2
Architecture	Leading Architect	Int1	2:33:02	Cs3
	Proposals, building	Int2	1:53:41	Cs3
	Detail and Building	Int3	1:53:45	Cs3
	Detail Plan	Int4	1:12:44	Cs3
	Proposals Aesthetics	Int5	1:47:45	Cs3
Mechanical Engineering	Product Development	Int8	2:15:54	Cs2
	Academic/Mechanical Engineer	Int1	1:58:04	Cs4
	Software/Electronics	Int2	1:28:36	Cs4
Electronics Engineering	Hardware/Electronics	Int3	2:55:03	Cs4
	Technician	Int4	1:55:43	Cs4
	R&D	Int11	1:39:12	Cs2
Aerospace Engineering	Academic/Control Design	Int5	2:40:15	Cs4
Environmental Engineering	R&D /Interaction Artist	Int6	2:44:17	Cs2
	Quality Manager	Int12	1:54:06	Cs2
Civil Engineering	CEO	Int13	1:35:57	Cs2
Biology	R&D	Int14	57:40	Cs2
Industrial Design	Industrial designer	Int7	1:14:28	Cs2
	Industrial design student	Int1	1:38:39	Cs5
	Industrial design student	Int2	1:34:30	Cs5
	Industrial design student	Int3	2:17:20	Cs5
	Industrial design student	Int4	1:52:22	Cs5
	Industrial design student	Int5	1:23:41	Cs5

Designers and non-designers from several background and activities answered the interview based on several topics regarding the designing activity such as, motivation, planning, management, teamwork and stakeholders among other aspects (for more detail see Appendix A). An introduction to the topic of *Value* is made at the beginning of the interview. The most descriptive and informative answers lead to the selection of interviews according to the objectives of the research, planned studies and cross-case analysis. A set of 35 interviews was selected from a total of 55. The 56 hours of interview raw data went through several rounds of analysis. Each interview transcript was subject to an iterative coding procedure in Atlas (www.atlasti.com).

The interview was a good method to assess a more reflective state of the interviewees, allowing them to explain what they are doing, have done, or intend to do, and may give reasons for their actions. This reflective talk provides a different window into practical reasoning and interviewees' discourses on the lessons learnt through years of experience working in several projects. In addition, they may report thoughts and concerns that they do not refer to while designing that help to clarify their notions about situations. It is assumed that interviewees' self-reports are reliable, while other sources of data, namely meetings, give other and complementary perspectives. The interviewees' diverse background from the case studies in Interaction design and mechanical engineering provided a broader analysis across design.

Meetings

The observation and analysis of meetings provided multiple perspectives and layers of meaning of the same utterances, circumstances and intervenient. The researcher identified multiple layers of analysis in consonance with the research objectives, dimensions of analysis and planned studies, as a way of dealing and identifying different phenomena in the same piece of data. The analysis of meetings required criteria for selecting utterances namely, that the utterances are comprehensible, truthful, congruent with the actor's intentions and legitimacy of the performed acts. The analyses of meetings provided understanding through the depth and richness of detail in comparison to other methods. Meetings showed that situations of *MUDA* are complex to assess. Inherent processes to designing, such as iteration, interdependency and reviewing can only be empirically assessed through the observation and analysis of meetings. Situations of *MUDA* are recognized in instances of evaluation that include multiple aspects of influence in decision-making. Table 3.3 depicts the design projects, number of sequential meetings and the observation period per case study.

Table 3.3. Overview of meetings per case during the periods of observation

Data Source	Case Study 1	Case Study 2	Case Study 3	Case Study 4	Total
	Graphic	Interaction	Architecture	Engineering	
Design	**Temporary Exhibition**	**Interactive solutions**	**Train interface**	**Robot**	
Meetings	6	7	7	8	28
Observation	6 weeks	4 weeks	5 weeks	5 month	

Research diary

Besides other sources of data such as visual documents, the research diary showed to be quite useful in situating the researcher in the timeline of the observation periods and recalling circumstances, ideas, thoughts, descriptions and insights, notes and illustrations of spontaneous analysis of pieces of data.

3.5 Assessment

The normative dimension in designers' behavior is concerned with *Value* questions implicit in the intentions of giving form to purposes, or explicitly expressed in verbalizations and physical actions that provide the best evidence for what do designers *Value*. In the context of practice the designer focuses his/her practical reasoning in choices about what to do, regarding ends and means and has a valuation component (Argyris et al., 1985). In addition, the identification of competent performance takes place in instances where mistakes are recognized and intervention is requested and taken. Thus, in seeking to discover rules of interaction in situations of *MUDA* and evidence for what designers *Value* in such circumstances leads to observing situations of less/successful performance. Protocol analysis is one of the four primary techniques currently available for studying designers (Gero, 2010) converting verbal utterances to data. The use of verbal protocols (Newell and Simon, 1972) to understand human problem solving became a method that has since been used and developed to understand behavior and is the method currently in use to study designers (Jiang, 2011).

The assessment of Lean Thinking in designing was, in a first stage, focused on the assessment of *Value* and *MUDA* based on the semantic analysis of interviews, design meetings and research diary notes. The analysis of the transcripts of designers' quotes was based on the identification and coding of descriptions of situations where *MUDA* played an influence in the design process. The investigation of *Value* aimed to identify characteristics of designers' approaches that could indicate how do designers assess *Value* in design. The study of situations of *MUDA* in the design process and its relation with what designers' *Value* and coping actions, aimed to understand how these mechanisms help prevent or coping with *MUDA*, and transform *MUDA* into *Value*. Due to the frequent occurrence of moments of *Value* judgment and *MUDA*, in idea generation, idea solution and conceptualization phase, the study was initially focused on the analysis of these stages of the design process. However, after some rounds of analysis it became evident that *MUDA* occur in any stage with particular incidence in the beginning and end of the design project. The quantitative dimensions of incidence, frequency, dominance and specificity, and the qualitative dimensions of semantic similarities and differences such as terminology and representation, determined means of assessment for cross-case analysis. The study of these and others dimensions of analysis (Table 2.3), were guidelines to empirically assess what designers' *Value* in instances of communication and decision-making. Analysis was accomplished through gradual and iterative studies, in a total of 10, intertwined with stages of data collection. Selection across the interviewees' background and presence per meeting is shown in Table 3.4.

Table 3.4. Overview of data collection per study and across the intervenient backgrounds

Background	Activity	Int.	Cs	I	II	III	IV	V	VI	VII	VIII	IX	X
Graphic design	Leading designer	INT 1	Cs1	▒	▒	▒			■	■	▒	■	■
	Design Producer	INT 2	Cs1	▒	▒			▒	■	■	▒	■	■
	Graphic designer	INT 3	Cs1	▒	▒			▒	■	■	▒	■	■
	Editorial designer	INT 4	Cs1	▒	▒			▒			▒	▒	
	Graphic designer	INT 5	Cs1	▒	▒			▒			▒	▒	
Social Communication	Producer	INT6	Cs1			▒							
Graphic and Multimedia design	Leader/Art Director	INT1	Cs2		▒	▒					▒	■	
	Interaction designer	INT2	Cs2		▒			▒			▒	■	
	Experience designer	INT3	Cs2		▒			▒			▒	▒	
	Illustrator	INT4	Cs2		▒			▒			▒	▒	
	Leading designer	INT5	Cs2		▒		▒	▒			▒	▒	
Literature	Copy Writer	INT10	Cs2				▒						
Software	Software Architect	INT9	Cs2				▒					■	
Architecture	Leading Architect	INT1	Cs3			▒				■	▒	■	■
	Proposals, building,	INT2	Cs3					▒		■	▒	■	■
	Detail and Building	INT3	Cs3					▒		■	▒	■	■
	Detail Plan	INT4	Cs3					▒			▒	▒	
	Proposals Aesthetics	INT5	Cs3					▒			▒	▒	
Mechanical Engineering	Product Development	INT8	Cs2			▒	▒					■	
	Academic	INT1	Cs4					▒			▒	▒	
	Software/Electronics	INT2	Cs4					▒		■	▒	■	■
Electronics Engineering	Hardware/Electronics	INT3	Cs4					▒		■	▒	■	■
	Technician	INT4	Cs4					▒		■	▒	■	■
	R&D	INT11	Cs2			▒							
Aerospace Engineering	Control Design	INT5	Cs4					▒		■	▒	■	■
Environmental Engineering	R&D /Interaction Artist	INT6	Cs2			▒	▒						
	Quality Manager	INT12	Cs2			▒							
Civil Engineering	CEO	INT13	Cs2			▒							
Biology	R&D	INT14	Cs2			▒							
Industrial Design	Industrial designer	INT7	Cs2				▒					■	
	Industrial design student	INT1	Cs5								▒	▒	
	Industrial design student	INT2	Cs5								▒	▒	
	Industrial design student	INT3	Cs5								▒	▒	
	Industrial design student	INT4	Cs5								▒	▒	
	Industrial design student	INT5	Cs5								▒	▒	
Year of data collection per study				2009		2009/2010			2009		2009/2010		

▒	Interview selected for analysis per study	
■	Presence in meeting per study	

Internal validity was elaborated on explanation building, which in turn was based on the identification of variants and invariants across case studies derived from the successive studies that lead to the identification of five main categorization systems, models of interaction and later to the integrative framework.

External validity aimed for transversal categorization systems across the multiple and nested case studies. Triangulation was tested with questionnaires. Four categorization systems were presented to a panel of evaluation constituted by 32 designers for feedback on Likert scale based questionnaires (see Appendices B, C, D and E). Designers have different backgrounds namely, Industrial design, Product design, Rehabilitation engineering design, Ceramics design, Arts, Architecture, Mechanical engineering, Communication and Graphic design. The age of the Portuguese, Brazilian and Ecuadorean designers vary from 25 to 36 years. Inter-rater reliability tests involved an external researcher for five of the categorization systems.

A codebook was elaborated on the sources of *MUDA* in design to support the development and fine-tuning the categorization system. The codebook entails sources, examples, sub-categories, application and criteria of analysis. The codes of the categorization systems are listed in Atlas.ti (www.atlasti.com), Excel, Word files and Interact (www.mangold-international.com/software/interact/) supported by notebooks.

The data of eight sequential meetings from the case study in Mechanical Engineering were shared with two other researches and transcripts were verified for a joint analysis and concurrent perspective (Gero et al., 2013).

3.6 Data Processing, Coding and Clustering Procedures

The interview transcripts were imported to Atlas.ti software (www.atlasti.com) workbench for content analysis. Representation of interviews data, results and findings were portrayed in Adobe Illustrator and Mathematica software (http://www.wolfram.com/mathematica) for alternative representations. These layers of analysis are further described in Chapter 5.

The analysis of the meetings followed a sequence of layers of investigation. Iterative coding was initially done with the videos in Interact software (www.mangold-international.com/software/interact/) and a more complex analysis was accomplished in Excel further explained in Chapter 5. Representations of the analysis of the meetings were illustrated in Excel maps and Interact plots.

In general, each study went through several coding stages. The first coding stage was regularly based on the analysis of prints of the transcripts for a manual and more intuitive assessment of the subject of the analysis. The second coding stage was based on a semantic analysis line by line, identifying verbs, nouns, adjectives, particular terminology, and meaning, to get acquainted with the cultural orientation of each interviewee and design office mindset regarding the design discipline and context of practice. The third coding stage was based on the identification of statements that describe drivers, purposes, the recognition of the situation, and its causes, effects and consequences, priority *Value(s)*, and interdependency towards decisions. The identification of codes and clusters contributed to the assertion of main axial categories leading to categorization systems (Saldaña, 2009). Clustering and systems of categories went through several phases reducing overlapping.

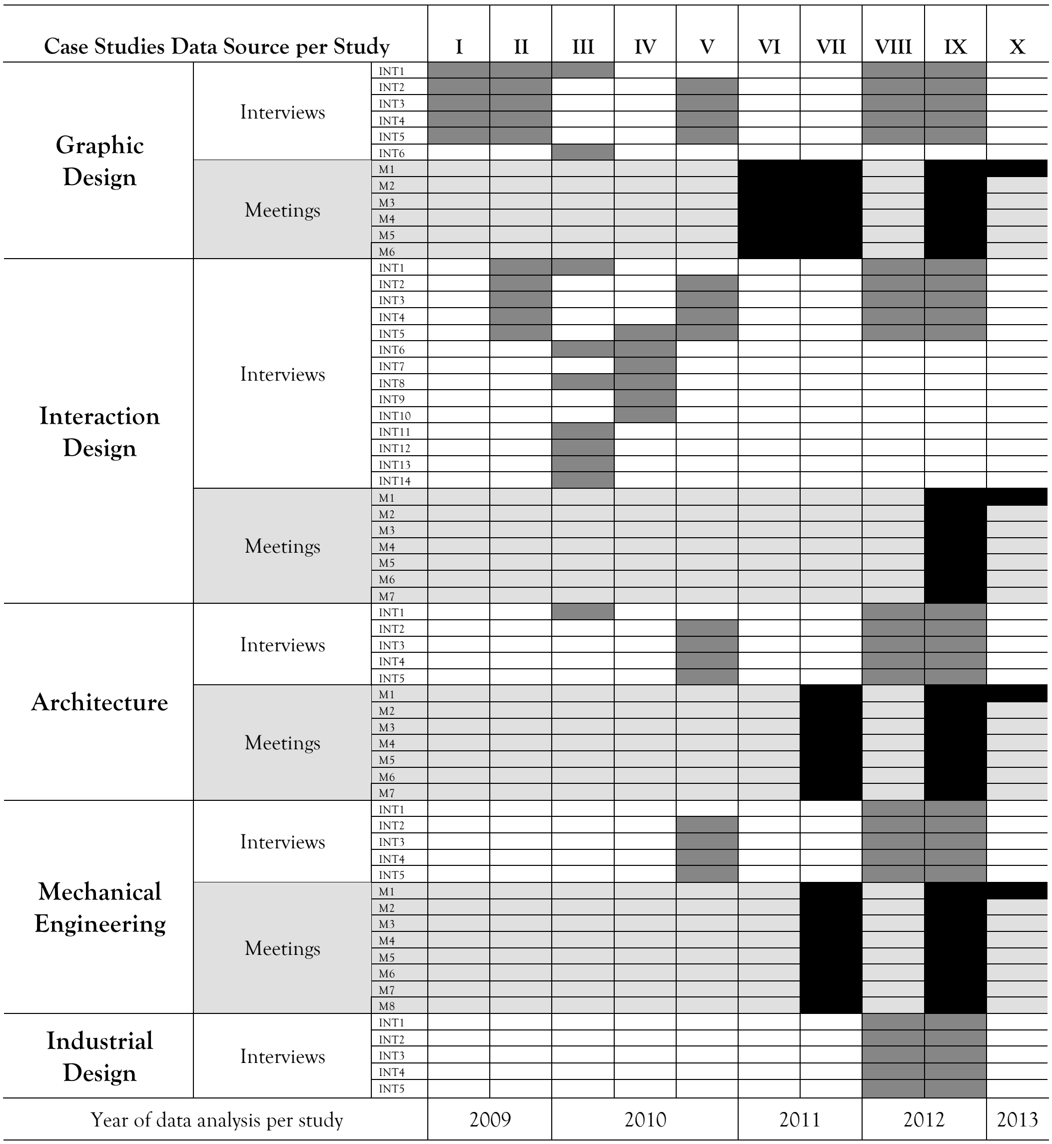
3.7 Data Analysis across the Studies

Analysis was accomplished through the 10 gradual and iterative studies. An overview of single and cross-case analysis is provided (Table 3.5).

Overview of single and cross-case analysis

Studies I and VI were pilot studies of within-case-analysis of interviews and meetings. Two stages of development of the cross case-analysis took place, based on interviews from Study II to V, and based on meetings from Study VII to X.

Table 3.5. Overview of data source and analysis per study in time across the Case Studies



The 25 selected interviews of designers were the raw data for analysis in Studies I, II, V, VIII and IX. Two other groups of interviews were used specifically, in Study III, for a comparison of five designers and five non-designers with design management tasks. Study IV, was a within-case analysis of the Interaction design case study, based on the comparison of interviews of designers from diverse backgrounds and one non-designer, which gave a multidisciplinary perspective on variants and invariants of designers approach.

The three audio and video recorded groups of sequential meetings were the data source for Studies VI and VII. This set of data is used in Studies IX and X together with the transcripts from the design project of the Interaction design case study.

Interviews-based Studies

The Pilot Study I, was the first attempt to empirically investigate *MUDA* and *Value* in designing based on the analysis of interviews from the Graphic design case study. A selection of five interviews was based on designers' different tasks, the leading designer, a producer, a non-permanent collaborator and designers focused on different types of design projects, such as exhibitions and publishers. The focus of the interviews analysis was the identification of *Value* from the designers' point of view and the identification of sources of *MUDA* in the design activity based on a preliminary literature review (Vieira et al., 2009a).

Study II extended the same focus of analysis to five interviews of the Interaction design case study. From the analysis of the ten interviews, 196 utterances were identified as situations of *MUDA and* 676 utterances describe what designers' *Value* (Vieira et al., 2009b).

As the interviewees reported many concerns related to the current situation of economic crisis, Study III, aimed to assess the influences and consequences of such circumstances in design as potential situations of *MUDA*. This was done through the analysis of ten selected interviews of managers with design and non-design background, all experts with management responsibilities and working in design environments. Design experts originated from areas such as Interaction design, Graphic design, Advertisement, Software design and Architecture. Non-design experts have backgrounds in Environmental Engineering, Management, Social communication and Civil engineering, working in areas such as R&D, Administration, and Project management. The interviewees work in three comparable design environments. A first stage of identification of statements regarding the influence of the economic crisis was made, and then followed by a selection of a few of them for comparison and the identification of influences, consequences and patterns of their relations (Vieira et al., 2010b).

Study IV describes the analysis of six interviews and characteristics of their design approaches. The selection of interviews was made based on those who exhibit more distinctive profiles and represent essential roles of a typical team. Each interviewee naturally differ in background, namely Software Architecture, Graphic design, Literature (working as copywriter), Mechanical engineering and Management, Industrial design, Environmental engineering and Interactive Arts. Interviewees' statements were analyzed and 756 utterances were grouped into a total of 126 invariant codes, 1250 utterances were grouped into a total of 578 variant codes, partially shared or particular. Statements content gave meaning to the codes and to the identification of variant and invariant characteristics across the interviewees (Vieira et al., 2010a).

The aim of Study V was to identify how designers deliver *Value* in design across disciplines. The selection was based on interviews that exhibited more complete descriptions of situations where the designers expressed the importance of a certain *Value* over others leading to a decision. The analysis was based on the search for designers' statements on priority leading to *Value* judgment towards decision-making. The sample comprises 16 selected interviews, four per case study. From the analysis of the interviews, 825 quotes describing designers' drivers in *Value* judgment for decision-making were clustered in five main categories of designers' *Priority Value* across disciplines (Vieira et al., 2010c).

Studies VIII and IX illustrate the analysis of interviews and fine-tuning of a categorization system of *MUDA* in designing. The selection of 25 interviews, five per case study was based on interviews that exhibited more complete descriptions of situations of *MUDA*. From the analysis of the 25 interviews, 582 utterances on designers' descriptions of such situations were organized into a final categorization system (Vieira et al., 2012a, 2012b).

Meetings-based Studies

The Pilot Study VI was the first attempt of analysis of meetings from the Graphic design case study. The study provided insight on the interaction between designers and stakeholders. The analysis searched for designers' and stakeholders' prioritization of issues brought into discussion in instances of explicit *Value* judgment leading to moments of decision. In a first stage, iterative coding in Interact software provided plots of the communication between the team elements. In a second stage, the meetings were mapped in Excel, in the search for instances of explicit *Value* judgment leading to a decision stage, which provided the identification of issues brought into discussion (Vieira et al., 2011a).

Study VII extended the same focus of analysis to the other two groups of audio and video recorded meetings from the Architecture and Mechanical engineering case studies. The priority issues and its related instances of *Value* judgment were mapped for each group of meetings in Excel files. The analysis provided awareness of iteration and interdependency of priority issues per design project (Vieira et al., 2011c).

Study IX led to a third stage of the analysis of meetings. This analysis was based on three sources of data, interviews, meetings and some research diary notes, and the fine-tuning of the categorization system on sources of *MUDA* and crucial actions in design (Vieira et al., 2012b). As previously mentioned, the analysis of four projects was possible due to the manuscript descriptions of the meetings from the Interaction design case study.

Drawing from previous results on a categorization system of the sources of *MUDA* and coping actions in design (Vieira et al., 2012b), Study X, attempts to investigate how designers prioritize *Value* in these particular circumstances. An in-depth analysis of the first meeting of the four design projects contributes to the knowledge and understanding of prioritization of *Value* in crucial actions to cope with *MUDA* situations in design across disciplines.

Studies Overview

In the following paragraphs, a summary of each study purposes, objectives and influence in the research is described. Table 9 depicts the research questions and dimensions of analysis across studies, data source and Lean Principles.

Study I and Study II - *Value* and *MUDA*

First attempts to identify variant and invariant characteristics of *Value* from designers' point of view and identification of the original types of *MUDA* in design based on the analysis of interviews transcripts from two case studies. A first and preliminary translation of *MUDA* in design is proposed (Table 2.2).

Study III – *MUDA* and coping mechanisms in crisis situations

In this study, the identification of characteristics of design managers' approach to cope with the influence of times of crisis brought insight to the identification of *MUDA* and Lean principles in the future studies.

This study was the first attempt to identify influences, measures, consequences, elements of coping mechanisms and behavioral examples in specific situations. At this point the identification of coping mechanisms started to be compared to the Lean principle of *Pull*. This study shows the importance of developing a culture of reviewing and awareness to specific situations in management activities.

Study IV – *Value Stream*: designers approach

Variant, invariant and specific characteristics of designers approach were identified from the analysis of interviews from designers with different background and activities. This study provides categories of what designers *Value* and drives their design approach. At this point these characteristics were compared to the Lean Principle of *Value Stream* as the course and frame of actions required to design.

Study V – *Flow*: conditions for decision-making

Variant, invariant and specific characteristics of designers' *Value* judgment for decision-making were identified from the analysis of interviews transcripts. At this point the management implications of the aimed explanatory framework became evident. Invariants gained strength with the identification of Priority *Value* in designing comparable to the Lean Principle of *Flow.*

Study VI – *Value* and *Flow*: interaction. Study VII - *Value* and *Pull*: iteration

Characteristics of designers' *Value* judgment for decision-making were identified from the analysis of meetings. Priority, iteration and interdependency of design issues are asserted as inherent to designing and relevant to decision-making and became criteria for the mapping of the meetings, that later became a base for the identification of *MUDA* situations. A model of interaction in instances of evaluation for decision-making in meetings is depicted.

Study VIII and Study IX - *MUDA* and *Value Stream*: sources and mapping

In these studies, the drivers for the translation of Lean Principles in designing are settled. Invariant characteristics of designers' mental and physical actions and behavioral examples result from the analysis of interviews and meetings. After many progressive analyses, designers' actions of multiple consequences conducted to a categorization system. In addition, an axial *Flow* chart was created to map *MUDA* in design.

Study X - Lean Principles and *MUDA*

This study is based on the analysis of the first meeting of each of the four design projects. The analysis is based on the categorization systems developed in the previous studies and a closer look to previously identified *MUDA* situations. A translation of the Lean Principles in design is proposed and discussed in Chapter 6.

Studies Overview across Research sub-questions

The studies for the translation of each Lean principle and *MUDA* are based on two sources of data, namely, interviews and meetings as shown in Table 3.6. The research attempted to empirically answer to the research sub-questions with the previously described and accomplished studies. Some questions were answered while other answers were partially fulfilled as further explained in Chapter 5.

Table 3.6. Overview of studies and research questions across Lean principles and *MUDA*

Lean Principle	Dimensions of Analysis	Research sub-questions	Study	Data
Value	Identify *Value* from designers' perspective	*What do designers' Value in design across disciplines?*	I, II	Interviews
	Identify how designers deliver *Value* in action	*How do designers deliver Value to the design process and design results in design meetings?*	VI	Meetings
Value Stream	Identify characteristics of designers' approach	*Do designers sharing the same design environment show the same design approach characteristics?*	IV	Interviews
	Mapping *MUDA* in design	*How to map MUDA in design across different design disciplines?*	VIII VII	Interviews Meetings
Flow	Identify *Flow* circumstances	*What are designers' Flow stops, breaks and conditions?*	IV	Interviews
	Identify *Flow* interaction sequences	*How do designers deliver Value to the design process and design results in design meetings?*	VI	Meetings
Flow	What do designers'	*Which invariant characteristics across different*	V	Interviews

and	*Value* and prioritize in decision-making	*design disciplines can be found in decision-making?*	V	Interviews
Pull	Interdependency and Iteration in design	*How do instances of Value judgment evolve in design meetings across design disciplines?*	VII	Meetings
	Identify *MUDA* in designers' discourse	*What situations of MUDA can be found in design across disciplines?*	I, II	Interviews
MUDA	Identify *MUDA* in designers' discourse and action	*How far situations of MUDA share invariant characteristics across design disciplines?*	VIII IX	Interviews Meetings
	Identify *MUDA* sources and coping mechanisms	*How do managers with design and non-design background working in the design environment cope with situations of the current crisis?*	III	Interviews
LP and MUDA	How do designers seize coping actions to cope with *MUDA* situations	*How do designers prioritize Value in crucial actions to cope with critical situations in design across design disciplines?*	X	Meetings

Variants and invariants across disciplines derived from the successive studies conducted to the identification of categorization systems and later to the integrative framework. As stated by Klaus Krippendorff (2006, p. 27) '*Scientific research is essentially re-search, a repeated search for patterns within available data.*'

In this thesis, the data collection increased as the complexity of data analysis evolved in a self-regenerating process. Analysis and results from the studies are depicted in Chapter 5.

Chapter 4 provides the description of the five case studies based in the design disciplines of Graphic, Interaction, Architecture, Mechanical engineering and Industrial design. Evidence is given to similarities, differences and specificities of each case study following a common structure of description.

4 Case Studies

What is the main purpose of…?

Graphic design: *'Communication, a visual way of conveying information'*

Architecture: *'Improve people's life quality'*

Interaction design: *'Provide informative and playful interactive experiences'*

Industrial design: *'Comply a function with a pleasant use'*

Engineering: *'Simplify people's life'*

How do designers refer to their addressees?

Graphic design: *'the reader'*, *'the user'*

Architecture: *'the person'*, *'the people'*

Interaction design: *'the people'*, *'the user'*

Industrial design: *'the user'*

Engineering: *'human-machine interface'*

(based on quotes of the interviewees)

This Chapter depicts a detailed description of each case study. The description follows the time line of the periods of observation. A concise illustration of the particular characteristics of each selected case and contribution to the research design is described, followed by a detailed description per case study. A brief introduction to results further explained in Chapter 5 is given.

The first case study, a Graphic Design atelier, was a pilot study made under exceptional circumstances of collaboration and data collection. This case brought many insights and fine-tuning of the research design. The second case study, small medium enterprise (SME) of Interaction Design solutions, brought insight on multidisciplinary and transdisciplinary aspects. The third case study, a classic and authorship Architecture office, provided the experience and observation of permanence and adaptive characteristics of a grounded design approach. The fourth case study was the challenging observation of a Mechanical Engineering design office based in the academic context that brought into evidence the scientific and instrumental links of design. The fifth case study was a complementary case that brought insight on Industrial Design students' awareness to *MUDA* in design and the relevance of a related framework in design educational programs.

4.1 Case Study 1. Graphic Design Atelier

The first case study, was an exceptional case of unusual accessibility that brought relevant data collection issues into view. This case study helped to refine the data collection plan, procedures and objectives. During the first observation period relevant questions became known for the design of the structured interview and for the research design. More attention was devoted to this case than to the others for the exceptional circumstances of data collection and an on-going review of the literature so that the final research design was informed and could support new perspectives on empirical observations. The first case study had a laboratory role in observing the intended phenomena of Lean Principles and *MUDA* in design from different angles, discovering and trying different perspectives and detailing the approach. It was a less structured approach of the researcher to the case. At the time, the scope of the investigation was broader and less focused than in the last data collection periods. The Graphic design case study provided considerable insight and hindsight into the issues under research.

The first case is a Graphic design consultancy located in Lisbon, in an Art and Design dedicated quarter. The office has a long-standing position in the market and dedicates its design activities to projects of national and international context relating to illustration, publishers, temporary, long-term and cyclical cultural events, such as exhibitions and institutions' image, such as museums.

The office has a small structure of eleven persons, of which nine constitute the design group, seven designers and two design producers. Designers and producers have background in Illustration, Visual design, Graphic and Communication design and specializations in Editorial design and Cultural communication. Three of the designers experienced the design activity in other cultures when living in Finland, England and United States for graduate and post-graduate studies. The dimension of the permanent team is based on the assumption that smallness of scale fosters mutual trust in this design group, which specific characteristics naturally solve emergent problems. The space outline of the design office is illustrated in Figure 4.1.

The office has its own design philosophy. They follow a certain line of graphical expression of what is essential, avoiding the superfluous. Words on the printed page are thought to be seen not heard. They attempt to get concepts across the meaning of the words, embodied in letters, through an economy of optical expression. They cultivate the idea that the graphic image of a project must correspond to the tensions and pressures of its content. Their Graphic design approaches are experimental and concepts derive from exploring solutions.

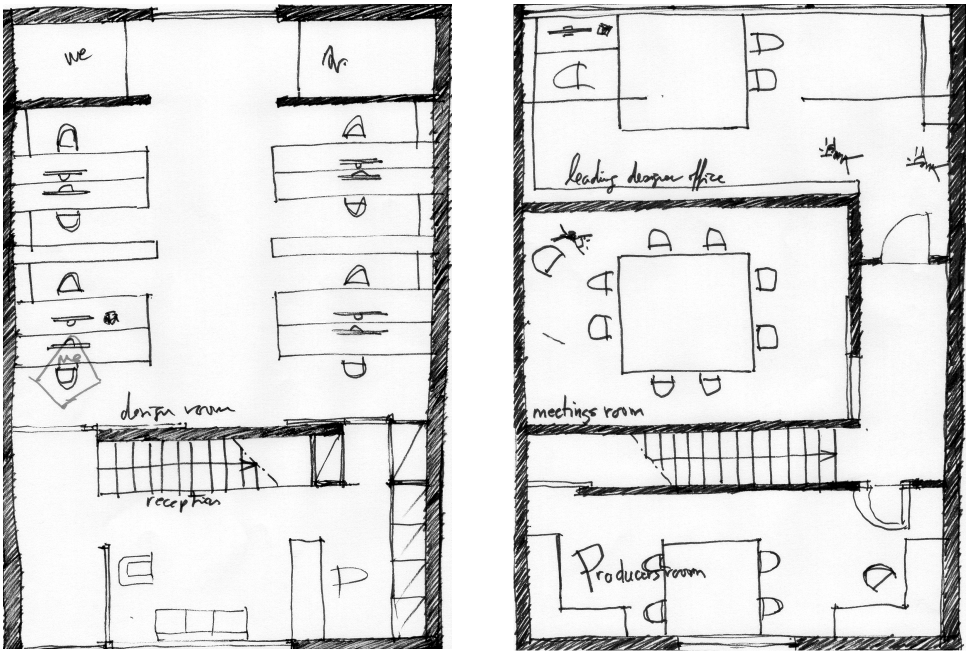


Figure 4.1. Outline of the ground and first floors of the Graphic design atelier

During the observation period of six weeks, five projects were followed namely, the design of a temporary exhibition, the development of the graphic design elements for an annual event, and three long-term partnerships, two with publishers for the design of book covers and one with an academic institution for the design of its corporate image.

The interviews of the seven designers and the two design producers were audio and video recorded. These pilot interviews followed a semi-structured interview of open questions based on the main topics that later framed the definitive half-structured interview.

The project was about the design of a temporary exhibition. During the period of observation six meetings involving the client's team took place. Meetings took a total of 12h: 06min. It was possible to follow the development of the design from the beginning, the client approval of the design and the first meeting of detail design and production plan. Table 4.1 illustrates the details of the meetings and the presence and background activity of each team member.

Table 4.1. Overview of meetings during the period of observation of the design of an exhibition

Week	**1st**	**4th**	**5th**			**6th**
Meeting	1	2	3	4	5	6
Duration	2h: 21 min	1h: 59 min	3h: 48 min	42 min	1h: 27 min	1h: 58 min
Topic	First concept ideas	Meeting of the client's and the design teams	Discussion of the exhibition content	Visiting the site with construction team.	Presenting a final solution to the client.	Detailed discussion of production plan
Stage / **Team members**	**Development of ideas**	**Task clarification**	**Analysis of requirements**	**Context analysis**	**Presenting final solution**	**Production planning**
Client project manager	■	■			■	
Client Historicist 1		■	■		■	
Client Historicist 2		■			■	
Client design manager	■	■	■	■	■	
Leading designer	■	■	■		■	■
Graphic designer	■	■	■		■	
Design Producer 1	■	■	■	■	■	■
Architect				■		■
Designer Producer 2		■	■	■		■
Designer of scenarios			■	■	■	■
Construction team				■		

The first three weeks were dedicated to the generation and development of ideas. The second meeting took place in the fourth week for task clarification. After meeting two the participants became better acquainted, the argumentation for discussion and the process itself were flowing, and the meetings exhibited more situations where the team members expressed the importance of certain *Value(s)* over others leading to moments of decision. After meeting two the design process was in a further agile state of development.

In meeting three the design team had a detailed discussion with the client main representatives about the content and structure of the exhibition. Issues such as conditional objects, the set of elements to exhibit, contract details, and fine-tuning costs and budgets were discussed. In meeting four the design, client and construction teams met at the future exhibition site, to discuss the implementation and completion of the works. The meeting was focused on finding effective approaches to cope with the on-going construction of the exhibition, remaining undefined elements, timing and planning. In meeting five the final solution was presented to the client's team. The leading designer started to explain the exhibition concept and structure of the general solution, then he described each sub-solution in more detail giving a visual image of the solutions representations and content. During this meeting several sub-solutions were elaborated through team discussion. The design team required from the client information about the contents of the exhibition. From the client's team, some requests about what lists of elements to provide and negotiate with other stakeholders were made. Issues such as following meetings, production planning, time schedule, deadlines and emergence of final decisions, awareness of risk failures due to technology conditions, outsourcing and costs control, protocol for information exchange and additional ideas that lead to the completion of the exhibition design were discussed.

In meeting six, five members of the design team started the detail design stage, discussing and fine-tuning the materialization of sub-solutions, fine-tuning the production plan of the exhibition, deadlines, schedules, project management, costs and budgets.

Moments of reflection regarding the design of the exhibition, the process or the meetings itself were observed in all the six meetings. The meetings one to five provided insights into the interaction between the design team, the client's team and other stakeholders while meeting six provided insights on how interaction occurs within the design team. *Value* judgment became more frequent during the stages of analysis and more clearly expressed during the meeting three to present the final solution. A more detailed discussion took place in the production planning meeting as the design evolved towards completion.

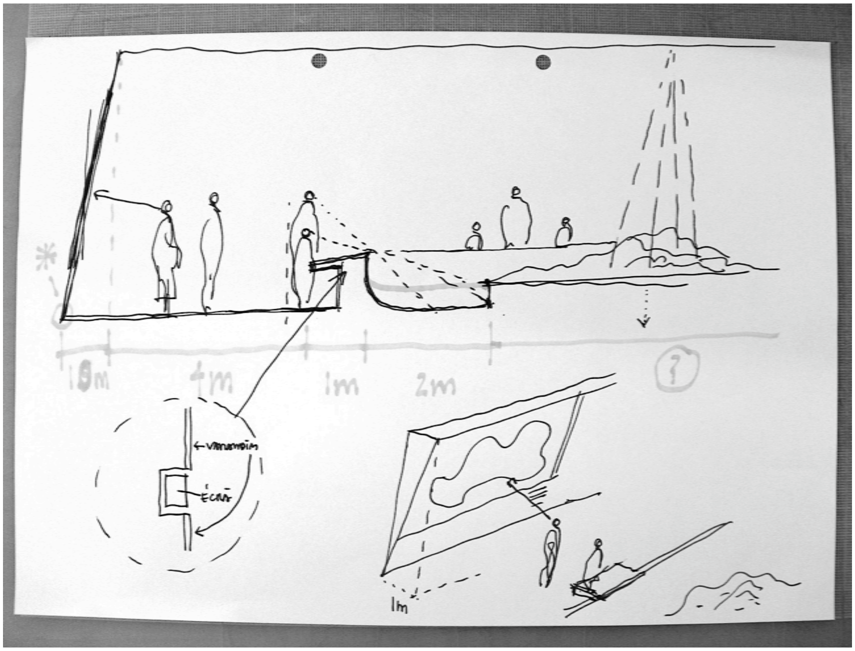


Figure 4.2. A sketch of the design of the exhibition (by Henrique Cayatte)

The office fine management is reflected in the low rate of *MUDA* issues further explained in Chapter 5. The single high incidence that indicates a management issue to solve relates to *Information assessment and Information transfer* from the clients. Content Information is often delivered to the office without consistent research, selection and organization from the clients. Delayed information content delivery causes over production in time and Graphic design is mostly dependent on information content to evolve, however some *MUDA* is necessary.

4.2 Case Study 2. SME of Interactive Design Solutions

The second case study was a rewarding experience of observation and interviewing individuals with different backgrounds working in the same design environment. This context allowed the assessment of variant, invariant and specific characteristics of designers' approaches, particular design issues of the interactive design purposes and management concerns of an emergent design discipline.

The second case study was a SME that provides Interaction design solutions, located in Lisbon, in close proximity to research institutes. The company gained a prominent position in the national market when it emerged as a leading group of Interaction design and research with new forms of transmitting information in a pleasant way. The company dedicates its design activities to projects of national and international context that relate to information systems, emergent technology, temporary, long-term and cyclical cultural events, such as exhibitions and museums, interactive solutions for dance and theater plays, and research and development of innovative solutions. Some talks were also given during the staying period.

The company employs 130 persons. The design group has 17 members. Its structure entails three main departments dedicated to research, sales and management and design. The case study refers to data collected during the period of observation in the design department.

Exceptionally, 23 interviews were accomplished with individuals from different background activities, of which nine are designers. The selected interviewees have a background in Software Architecture, Mechanical Engineering, Environmental engineering, Civil Engineering, Literature, Biology, Management, Graphic Design and specializations in Illustration, Multimedia and Interactive Design, Advertisement and Research. Eight of the interviewees experienced the design and research activities in other cultures when living in the United States and Spain for post-graduate studies and professional practice. The outline of the space where the observation period took place is illustrated in Figure 4.3.

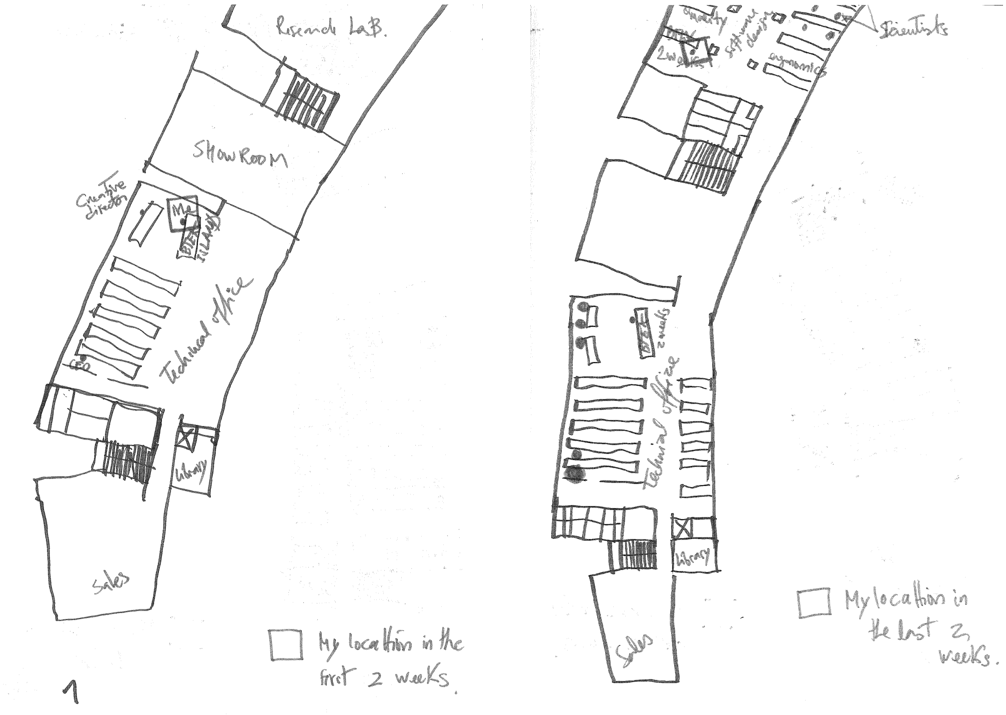


Figure 4.3. Outline of the design department of the SME of Interaction design solutions

The company follows a particular management philosophy based on a line of thought that stresses the importance and development of each one's feelings of responsibility and freedom. They do not follow a particular line of expression. They have an experimental design approach. They attempt to get concepts across: intensive sessions of brainstorming; research and ideas materialized in initial stages of technological artisan. The company follows the Agile Development with Scrum management philosophy for product and software development (Takeuchi and Nonaka, 1986; Schwaber, 2004; Sutherland, 2004).

The design and management departments face emergent complex design processes and management issues related to reproducibility. They detect undeveloped knowledge or knowledge that does not yet exists in a stable and organized structure. They try to cope with these gaps supporting their design culture with relevant publications (Buurman, 2005; Sterling, 2005). Besides giving the chance of studying the design approach of designers with different backgrounds and activities, this case showed other perspectives to investigate *MUDA* in a design environment where many times the design process has to advance to a stage of development of testing to finally check feasibility, thus some *MUDA* is necessary.

During the observation period of four weeks, I had the chance to follow one project namely, the development of interaction design solutions for a permanent exhibition of a museum devoted to a certain topic that cannot be disclosed due to confidentiality issues. The description of the observation of the design project and details about the interviewees are provided.

The nine designers have background in Software Architecture, Mechanical Engineering, Illustration, Advertisement and Graphic Design with nuances in Experience, Interaction and Multimedia Design. The interviews were audio recorded. These interviews followed the half-structured interview settled in the first case study.

The project was about the development of interactive design solutions to exhibit in a museum. The period of observation took four sequential weeks in which seven meetings took place. During this period direct feedback from the customer was gathered before meeting two. Meetings took in average one hour and a half in a total of 10h: 30 min. The client's representative travelled once from abroad to visit the company and evaluate solutions. It was possible to follow the development of two interactive design solutions from the beginning. Details of the meetings and the presence and background activity of each team element is shown in Table 4.2.

Due to confidentiality issues these meetings could not be recorded. However, detailed description and notes of the meetings were taken in the research diary. These manuscripts were focused on the identification and description of situations comparable to *MUDA* and coping actions.

Table 4.2. Overview of meetings during the period of observation of the design of interactive solutions

Week	**1st**	**2nd**				**3th**	**4th**
Meeting	1	2	3	4	5	6	7
Duration	1h:30 min	1h:40 min	1:00 min	2h:00 min	1h:30 min	1h:50 min	1h:00 min
Topic	Discussion of feasibility of concept ideas	Discussion of interactive solution and feedback from client	Discussion of the furniture design	Discussion of interactive solution and feedback from client	Discussion of feasibility of concept ideas	Preparing meeting with the client.	Detailed discussion of solutions
Stage / **Team members**	**Development of ideas**	**Analysis of requirements**	**Feasibility of solutions**	**Development of ideas**	**Development of ideas**	**Planning solution Presentation**	**Detailing and testing**
Leader/Art Director	■	■	■	■		■	■
Ergonomics designer	■						
Illustrator	■	■					■
Programmer	■	■	■	■			■
Multimedia designer	■	■		■	■	■	■
Creative designer	■	■		■	■	■	■
Project manager	■	■	■	■	■	■	■
Project manager abroad	■			■		■	■
Copywriter	■			■			■
Electronics engineer	■		■				■
Mechanics engineer	■		■				
Sales manager			■			■	
Industrial designer			■				
R&D					■		■
Animation designer					■		

In the first week one meeting took place while an external collaborator was getting feedback from the client. In this meeting the team discussed the feasibility of concepts and ideas meant for the first of eleven interactive solutions requested by the client. In the second week, and after receiving the client's feedback, four meetings took place dedicated to the analysis of requirements, development of ideas and feasibility of solutions to the second and third interactive solutions. The second meeting took place to discuss feedback from the client, mistakes in the presentations, necessary improvements and strategic changes. A second interactive solution started being discussed in this meeting. The third meeting was specifically planned to discuss with the industrial designer and the product development team the implementation of a solution in a piece of furniture. The fourth meeting took place to discuss a second round of feedback from the client and to further develop ideas for the second interactive solution. In meeting five the feasibility of concepts and ideas for the second and third interactive solutions were discussed. In meeting six the team planned the next meeting with the client's team and prepared the solution to be presented. Figure 4.4 illustrates a storyboard for an interactive design solution.

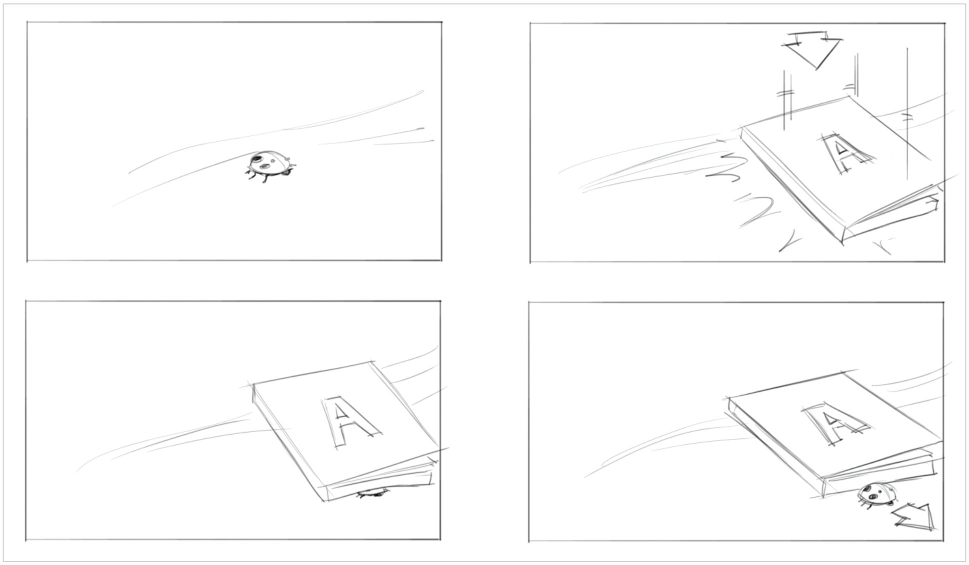


Figure 4.4. A storyboard for an interaction design solution

The client's team made requests to be taken into account. In meeting seven an extensive and detailed discussion about solutions details and planning of tests took place. The designers already knew each other, thus argumentation, discussion and process *Flow* were assured based on affluent information content.

In this particular case of an emergent design discipline with new and complex design management issues, it is a misfortune that meetings could not be audio recorded. Such data would have been a good base for the analysis of *Value* in decision-making.

In this case study an effective management is reflected on the low rate of *MUDA* issues. The incidences that indicate management issues to solve are *MUDA* related to cognition, execution and interdependency. Although the complexity of the context of interaction design and the occurrence of defects in the development process can momentarily suspend decision-making, the main *MUDA* situations relate to frequently changing the mind set, difficulty in creating mental space, using predefined solutions disregarding the design problem context, and incongruity of interdependent design activities or designers, especially in the creative stages. From the evidence that situations comparable to the Lean concept of *MUDA* in design can have negative but also positive effects, *MUDA* became an essential part of the design process, including the creative stages.

On the other hand, an effort is made to avoid advance work without demand. Anticipating problematic situations shows a high importance as a preventive action which denotes concern for a good management of anticipation.

4.3 Case Study 3. Architecture Design Office

The third case was an Architecture design office located in Porto district, more specifically in the city of Maia, in the ground floor of a nice building designed by the Pritzker Prize 2011, Eduardo Souto de Moura.

The office has a long-standing position in the market and dedicates its design activities to projects of national and international context that relate to public buildings, urban interventions such as parks and metro interfaces, social housing, private housing, institutions, urban equipments and competitions.

The third case study was an exceptional experience that similarly to case study 1, provided unusual amounts of accessible data. With this case I had the chance to observe and interview architects with very similar backgrounds, all graduated from the Faculty of Architecture of the University of Porto, performing similar and differing activities and working in the same design environment. Data collected from this case shows the best examples of verbalized thinking processes underlying designing collected in this research.

The office has a small structure of 9 architects out of a total of 10 people. Four architects experienced the design activity in other cultures when living in Finland, United States and Switzerland for post-graduate studies and professional activity. Besides the common background, the architects focused their activities in specific tasks, namely, development of proposals, detail plan, building, social housing, systems structures and aesthetics of proposals.

The dimension of the permanent team is based on the idea that the problem of collective action in designing can best be solved in small communities with few possessions to quarrel about. The space outline of the architecture office where the observation period took place is illustrated in Figure 4.5.

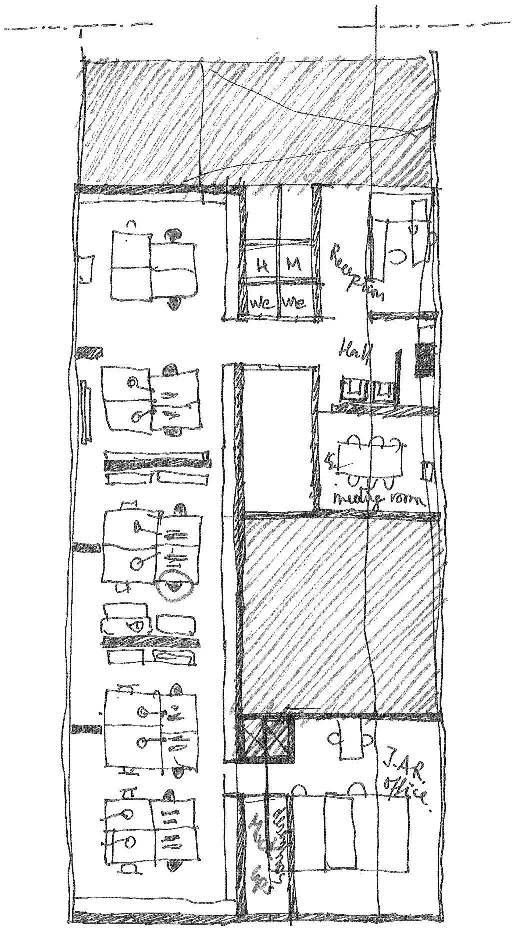


Figure 4.5. Outline of the Architecture design office

The office follows the authorship philosophy. Concept design guidelines and decisions are centered on the leading Architect, João Alvaro Rocha. They follow a certain line of thinking about Architecture were the superfluous does not take place. The spatial organization and composition, modulation, detail and materials must be part of the whole concept. Designing is a reflective practice of questioning the purpose, use, effect and coherence of solutions. This coherent approach with results published (Craca, 2003; Neves, 2008) has a recognized language in the Architecture domain.

The office faces design and management issues derived from recent policies, such as energy certification, introducing new variables in the design process. The architects adhere to designing systematized design solutions that fulfill policy and spatial qualities as well as different design approaches.

During the observation period of five weeks I had the chance to get acquainted with four projects namely, the long-term collaboration with Metro of Porto to design the interfaces and railways surroundings, the design and detailed plan of an office building, the long-term work developed in social housing, and following the project initiated at that time, a train interface. In addition, the architect explained and sketched the principles behind some of his other projects, these statements were audio and video recorded.

This case study was appropriate for studying the design approach of architects with the same training but differing focus of current activities. This case also showed other perspectives to investigate Lean Principles and *MUDA*, in a design environment that demands high coherence of design proposals, a central role for sketching in developing and testing ideas and concepts and decision-making centered on the leading architect.

The nine architects with special interest in the development of specific and dissimilar tasks gave interviews that followed the half-structured interview settled in the first case study. The interviews were audio recorded.

In case study 3 the project was about the design of a train interface. Seven meetings took place in four weeks of the observation period. During this period direct feedback from the client was gathered twice, after meetings three and five. Meetings took in average two hours, with exception of two short meetings of 37 and 45 min and 1 meeting of 3h: 32 min, where the design proposal was explained to the client's representative. Meetings took a total of 12: 30 min.

The client's representative travelled once to visit the office for a meeting to evaluate the proposal. The leading architect travelled once to meet the client's team, before meeting three. It was possible to follow the development of the design interface from the beginning. Details of the meetings and the presence and background activity of each team member are shown in Table 4.3.

The architects work with each other for a long time, thus argumentation, discussion and process *Flow* were assured and very rich in terms of content. Design meetings are further described.

Table 4.3. Overview of meetings during the period of observation of the design of a train interface

Week	1st			2nd		3rd	4th
Meeting	1	2	3	4	5	6	7
Duration	1h:47 min	2h:22 min	37 min	2h:04 min	3h:32 min	1h:47 min	45 min
Topic	Context analysis, First concept ideas	After a visit to the place with construction team	Analysis of the program for a global solution	Detailed discussion of the program and solution	Presenting the solution to the client.	Detail design of several issues	Production of drawings and visuals to exhibit
Stage	**Context analysis**	**Development of ideas**	**Task clarification**	**Analysis of requirements**	**Presenting solution**	**Detailing**	**Preparing final presentation**
Team members							
Client project manager				■	■		
Leading architect	■	■	■	■	■	■	■
Architect organization	■	■	■	■	■	■	■
Architect details	■			■			
Architect infrastructures	■	■		■	■		

In the first week three meetings were dedicated to the analysis of the urban context of intervention, development of ideas, concepts and task clarification. A visit to the place of intervention was made together with the client and construction team. During this period the architect's team got acquainted with other collaborating engineering teams and policies to consider regarding the type of project and place of intervention. In the second week two meetings took place for a more detailed analysis and discussion of the requested program and systems of the train interface. The architects developed two solutions and presented them to the client's representative. Design issues such as global solution, supporting structure, people's circulation, budgets and detailed design, such as the design of the hedge were discussed. In the third week a meeting to discuss detail design solutions took place.

After stabilizing the global concept, the architects were focused on detailing essential design issues with influence on the modulation and structure of the global design solution and developing complementary spaces for specific functions. In the fourth week the design team was dedicated to planning and preparing a final presentation for the client.

Figure 4.6. A sketch drawn to explain two projects (by João Alvaro Rocha)

In this case study there is a low rate of *MUDA* issues. The incidences that indicate management issues to solve are related to interdependency and the need to optimize design solutions. Although the context of designing in an authorship architecture office can frequently suspend decision-making of the design team, if centered on the leading architect, the main *MUDA* situations relate to the need to have time and create mental space to develop systematized design solutions that fulfill the new policies demands and spatial qualities of *Value* for the office design approach. In this design team an effort is made to advance work independent of the leading architect, anticipating deadlines and turning points in the design process. This effort shows a high importance given to preventive actions to manage anticipation and probability. Thus, once again, *MUDA* is recognized as an essential part of the design process.

4.4 Case Study 4. Mechanical Engineering Design Office

The fourth case study was an experience that brought opportunities for research collaboration and the chance to observe and interview engineers with different backgrounds and activities working in the same project. This case had the longest period of observation.

Researchers from the Delft Center of Systems and Control made a joint effort with a design team based in academic environment, more precisely at TUDelft, in a department responsible for the implementation of projects at the Faculty of Mechanical, Maritime and Materials Engineering. This design team works in collaboration with research staff, students and companies in the development of projects, prototypes and products.

Two projects were followed, the development of a robot hexapod for experiments and the design of control software for specific equipment developed by a group of Mechanical engineering master students. However, for the cross case analysis, the design process of the robot was richer and more visible than the control software project.

The case study refers to data collected during the period of observation, more specifically in two different spaces, the control software project was followed in meeting rooms, the robot design was followed in the design team daily office. Nine interviews were accomplished with engineers of diverse backgrounds and current activities.

Two of the interviewees experienced the design and research activities when living in Czech Republic, Portugal and the United States during graduate, post-graduate studies and professional practice. The space outline of the design team office and one of the meeting rooms used in the observation period are illustrated in Figure 4.7.

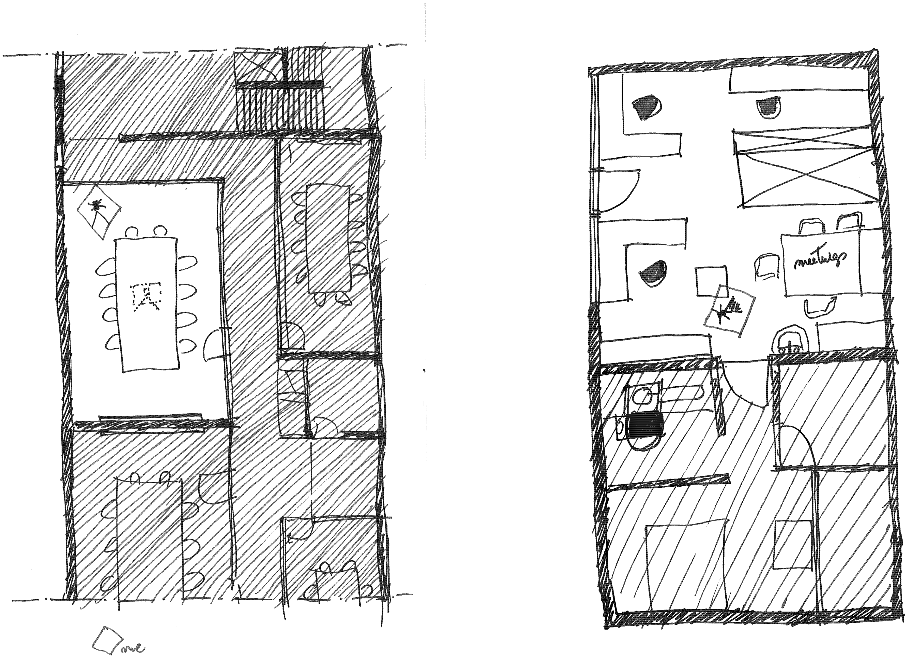


Figure 4.7. Outline of the spaces were the projects were followed: the control software, and the robot

Control design is an early discipline in the field of Engineering that according to the interviewees still has a long way to go and evolve beyond its half-century of development. Therefore, there is a lot of space to create, experiment and structure the knowledge base of Control design.

The engineers and researchers of this project attempt to have a systematic but also experimental approach. They attempt to get concepts and ideas across meetings of discussion, literature review and keeping up-to-date with new technologies and results from the industry. As in the Interaction design case study, these engineers also materialize their ideas and concepts in initial stages of technological artisan. They face unexpected problems from on-going processes.

This case study gave the chance to study the design approach of engineers with different background and activities. This case also showed other perspectives to investigate Lean Principles, *MUDA* and coping actions in a designing activity that evolves with increased amount of necessary knowledge and information, invisible processes to the naked eye, minimal features and a shared concerned stated in the common expression of '*make it work*'.

The nine engineers, four from the software design and five from the robot project with different specializations and interests in the development of specific and dissimilar tasks gave interviews that followed the half-structured interview settled in the first case study. The interviews were audio recorded.

The robot design was settled as a subject of a research project with a support structure of two teams: two researchers, one of them the project manager; and a team of technical engineers with different backgrounds in Mechatronics, namely: Software, Hardware, Control, Aerospace and Mechanical and Electronics engineering.

Although the design was based on a previous similar robotic controller the team faced several unexpected situations and challenges. At least one engineer in this design project had previous experience in designing robot controllers. It was possible to follow the development of the robot from the beginning.

Eight sequential meetings took place during a period of observation of five months. In this case, the customers were the two academic researchers with an intended timeline for the research project. Meetings took an average of one hour in a total of 7h: 34 min. Meetings took place always after lunch at 14: 00 o'clock, with the exception of meeting three that took place at 13: 00 instead. Meetings were audio and video recorded. Details of the meetings and the presence and background activity of each team member are shown in Table 4.4.

Table 4.4. Overview of meetings during the period of observation of the design of a robot

Month	1st			2nd	3rd	4th		5th
Meeting	1	2	3	4	5	6	7	8
Duration	1h:06 min	1h:03 min	1h:08 min	52 min	34 min	51 min	1h:01 min	58 min
Topic	Detailed discussion about the specifications and solutions	Planning, outsourcing and power supply	Discussion about the Robot internal communication	Assembly of sub-parts, connections, testing and details	Discussion of software, defining tests and connections	Identification of problems, connections and detail	Assembly, Identification of problems, detailing and testing	Identification of problems, detailing and testing
Stage	Analysis of requirements	Production planning	Task clarification	Planning Testing and detailing	Analysis of requirements	Analysis of problems and detailing	Testing, analysis of problems and detailing	Testing, analysis of problems and detailing
Team members								
Leading Eng.	■	■	■	■	■	■	■	■
Electronics Eng.	■	■	■	■	■	■	■	■
Software Eng.	■	■	■		■	■	■	■
Technician	■	■		■	■	■	■	■

In the first month three meetings were dedicated to the analysis of specifications, team organization, production planning and task clarification. Meeting three was dedicated to the discussion of components. In the second month a fourth meeting initiated the testing and detailing tasks that last until the end of the observation period. The control aspects of the robot were introduced in meeting 4. Meeting 4 was a "bridge meeting", discussing some design considerations more in depth, attempting to make connections to other considerations while focused on the expected consequence of solutions. In the last two months the analysis of specifications, connection systems, power supply, fine-tuning costs, and the identification and analysis of problems were dominant issues. Meeting 6 was mainly targeted at a particular technical problem *'how to solve the overheating of the board'*. Meeting 7 reactivated the topics introduced in Meetings 1 and 4, such as the central processing unit (CPU) and batteries, during the testing process. Many robotic components, such as the microcontroller and battery were continuously discussed since the first meeting. Some of the team members had negative experiences working in teams. Argumentation, discussion and process *Flow* took some time to be assured. Figure 4.8 illustrates the working assembly of the robot.

Figure 4.8. Prototype of the Robot hexapod

In this case study the rate of *MUDA* reflects some management issues. The incidences that indicate management issues to solve are *MUDA* related to outsourcing, complexity, and execution. The complexity of problem-solving in engineering design, the occurrence of defects in the development process of the prototype, and the delay of outsourced components can suspend the process and decision-making. In this particular case, the design team of technicians had other projects to develop in parallel, besides students' emergent and non-scheduled requests that postponed attention to this project. Main *MUDA* situations relate to outsourcing, execution problems in the design of the boards, systems energy connections that failed during testing and synchronicity of functions. On the other hand, an effort was made to be as systematic as possible and manage time and efforts for discussion with short meetings. Figures 4.9 and 4.10 illustrate the schematics, calculations and other alphanumeric representations of the engineering designers.

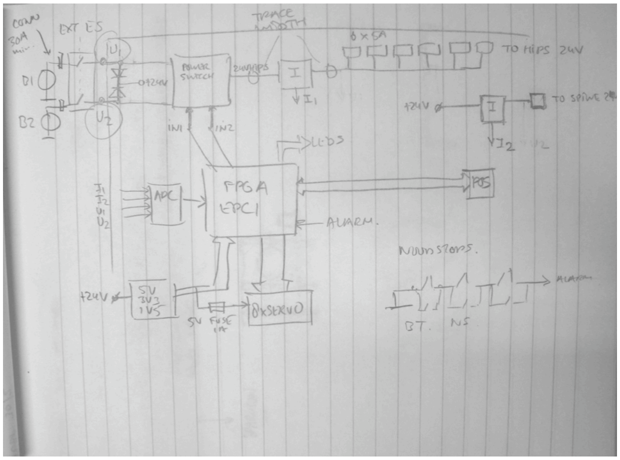


Figure 4.9. Schematics of main components and systems

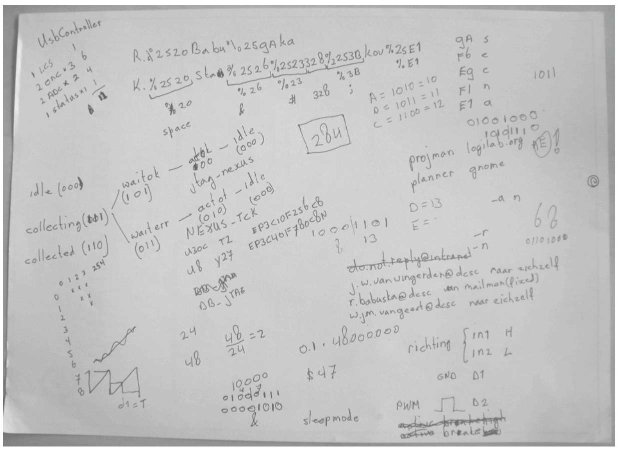


Figure 4.10. Calculations and other alphanumeric representations

4.5 Case Study 5. Industrial Design Students

Case study 5 is based on a teaching experience from the industrial design course at TUDelft. The course, the Bachelor Final project, brings together graduating students, faculty and client representatives to design and develop new products. Two project teams of five to six graduating industrial designers had the opportunity to experience working together for one semester. Each team was expected to deliver a physical prototype and a business plan with details of production, marketing and financial aspects for the new product or service introduction. However, this time students had to face a challenging design brief that asked for innovation and eventually invention.

Given the difficulties the students faced in dealing with the demanding assignment, this group of 11 Industrial design students seemed to be appropriate to investigate Lean Principles and *MUDA* in product design in the educational context. As the research coach of this group of students, I had the opportunity to follow the development of their product concepts with regular meetings during one semester. Delft industrial design students, experienced in using methods in design tasks, were challenged to apply the design methodologies in such a way as to go beyond a mere redesign or incremental innovation. Basic supporting textbooks of structured methods include models such as the DIM-model (Buijs, 2003) the Delft model (Roozenburg, Eeckels, 1995), the Delft Innovation Method (Buijs, 2012) among others (Delft design guide, 2010). In this assignment, students were asked to design a brainteaser.

Five students were asked to answer the half-structured interview settled in the first case study. In addition, students' answered to a questionnaire on the influences and consequences of using learnt structured design methods. Four aspects emerged from the analysis of students' statements, namely: advantages and disadvantages of using structured methods as the usual procedure; Influence of the nature of the assignment to routine design practices; Identification of the new actions they had to perform; and lessons learnt from the new product development experiences (Vieira et al., 2011d).

Delft Industrial design students made a comparison between their usual structured method and the differences and difficulties they found in this assignment. Although students refer to the importance of structure and planning, they also expressed that such assignments needed more freedom of actions and not so much framed mind. Table 4.5 shows the students' statements.

Table 4.5. Advantages and disadvantages of using structured methods as design procedures

Structured Method as Usual Procedure	
• **Structured** • **Provides Planning** • **Guiding principle**	• **Not so applicable** • **Framed beginning** • **Creative restriction**
'It gave structure to the design process and planning' *'Very applicable. I see product development as a continuous process'* *'I knew the phases of this method so I could work in a structured way and make a time planning'*	*'Not so much influence as normal'* *'Mostly disadvantages because you try to start with something you already know, which leads to puzzles people already know.'* *'The design of a brainteaser needed more freedom'* *'In this case the normal procedure didn't work for me. To create something inventive it wasn't enough to just use my brain. I needed more input to create more output and used a lot of pictures and design books to invoke more concepts.'*

Students identified four design practices that suffered influence in this learning experience, namely, brainstorming, field search, modeling and idea generation as shown in Table 4.6. Brainstorming activities did not easily provide the chance to convert ideas into concepts. The idea generation stage got broader than usual and more attention was paid to innovative ideas rather than technical calculations. Modeling activities to test working principles and concepts were anticipated to the beginning of the process. Students referred that the methods learnt during the bachelor course were important instruments for gathering and classifying things.

Table 4.6. Influence of the nature of the assignment to routine design practices

Practices	Industrial design students' statements
Field search	**Routine**
	'Important to see what exists in the market.'
Brainstorming	**Different**
	'Brainstorming showed the difficulty of the task, it was often impossible to convert the movements and experiences into a puzzle.'
Modeling	**Different**
	'Modeling had more influence than usual. It was very important. A requisite to test the difficulty.' *'To test movements and experiences, shape, the working principle and the look of the product. To be sure that the puzzle works.'* *'In the idea phase, from beginning to the end. To convince the client of the model working principle. Models were very important in the communication with the users.'*
Idea generation	**Different**
	'More attention goes to innovative idea generation and less attention goes to technical and dynamical (force) calculations.' *'I had to put more time in the idea-generating phase, whereby I found it difficult to generate new and innovative ideas.'* *'The concept phase took more time because it was harder to come up with creative ideas. Next to that it was harder to verify different concepts. All puzzles look quite easy when you look at them and you only start to realize the difficulty when you pick it up. This requires more user tests than normal.'*

In this teaching experience I observed that students had difficult times in situations where efforts would not lead to *Value* creation and that *MUDA* was frequent, especially in creative processes for radical innovation. Students showed awareness but also its absence to *MUDA* situations in design.

Chapter 5 provides explanation of the analysis, describes the progression of the studies, results and development of categorization systems per Lean principle and *MUDA*. Each sub-chapter concludes with the integration of results and answers to the sub-research questions.

5 Analysis and Results

> *'... when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be.'*
>
> Sir William Thomson, Lord Kelvin *in*,
> Ian Whitelaw, 2007. *A measure of all things*, p. 6

In this Chapter the description of the studies follows the investigation of each Lean principle and *MUDA*, for which categorization systems summarize the integration of results. As the case studies are non-comparable but provide complementary information, the identification of dimensions of analysis as a means of making things comparable was a relevant step in order to identify categories of a qualitative nature. The quantitative dimensions of frequency, incidence, dominance and specificity, and the qualitative dimensions of semantic similarities and differences determined means for explanation building and the identification of variants and invariants across the case studies. Findings of the research sub-questions are given in the end of each sub-chapter.

The three-fold expected contributions of this research lead to the development of categorization systems that would support the claims. First, extending the Lean Principles to design and product development, secondly, developing an explanatory framework of Lean principles and *MUDA* within the actors of design contexts, thirdly, contribute to the knowledge about designers' across disciplines and improve behavior.

5.1 Development of Categorization Systems

The search for transversal categorization systems useful to the research goal led to progressive studies and diverse layers of results. Five main categorization systems derived from the studies are briefly described and explained. Four of these categorization systems relate to the Lean Principles of *Value*, *Value Stream*, *Flow* and *Pul*l in design, respectively:

- **Categories of *Value* for designers.** Study I and II provided the identification of nine categories of what designers' *Value*, namely: *motivation*, *aspiration*, *inspiration*, *learning*, *gaining knowledge*, *prevention*, *providing structure*, explicit *values* and *application results.* This categorization system relates to the designer as individual.
- **Categories of designers' approach.** From a comparison with Aristotle categories of substance (1986, 1994, Portuguese translations). Study IV depicts six categories of designers' approach, namely: *environment*, *team*, *designer*, *process*, *management* and *performance.* This categorization system relates to the designer approach in teamwork.
- **Categories of *Priority Value* for decision-making.** Study V provided the identification of five categories of drivers of *Priority Value* for decision-making, namely: *emotion-based*, *intuitive-based*, *rational-based*, *experience-based* and *constraint-based.* This categorization system relates to the designer's awareness of the design and teamwork.
- **Categories of *Priority Issues* for decision-making.** Study VI and VII provided the identification of five categories of *Priority Issues* in instances

of *Value* judgment in design meetings, namely: *Situation-based, Strategy-based, Measuring-based, Validation-based* and *Collaboration-based.* Insightful results from Study III provided elements of mechanisms to cope with economic crisis situations.

The fifth categorization system relates to the identification of *MUDA* as sources of *critical situations* and *crucial actions*, namely:

- **A Meta-level behavior framework.** Preliminary translation of *MUDA* in design is depicted from studies I and II. Study VIII and IX provided the identification and fine-tuning of a framework that entails seven categories of twofold utility: sources of *MUDA* as *critical situations* and sources of *crucial actions* to cope with the circumstances. The categories are: *Dosage, Planning, Framing, Information Assessment, Information Transfer, Interdependency* and *Envision.* This categorization system relates to the designer awareness of *MUDA*, its influence in the design process and coping actions.

The development of each categorization system is further described. Four categorization systems were presented to a panel of evaluation for feedback on questionnaires (Appendices B to E). Inter-rater reliability tests were accomplished with a researcher external to this research. The investigations of the dimensions of analysis and research questions per Lean Principle and *MUDA* are described.

5.1.1 Investigating *Value* in Design

Categories of *Value* for designers

Studies I and II report the analysis of ten interviews from the Graphic and Interaction design case studies. When confronted with the questions regarding *Value* in design, the interviewees exposed two different approaches: the expert designers felt the need to retain a broader view, reflecting on experience and identifying tangible and intangible *Value* aspects as designers and citizens; the others focused on the office daily life, projects, motivations, organizational issues and stakeholders. The analysis leads to nine sub-categories based on 52 codes (Figure 5.1). Table 5.1 shows codes of higher incidence per sub-category.

Table 5.1. *Value* sub-categories with higher incidence in Graphic and Interaction case studies

	Behavioral examples	
Sub-categories	**Case Study I**	**Case Study II**
Motivations	Creation and materialization of ideas; find the way to proceed; engage others	Search for essentials; find the way to proceed; find a solid concept base
Aspirations	Social intervention	Create emotional cycles; create novelty; social intervention.
Inspirations	Unexpected situations	Unexpected situations.
Learning	Rethink in time and experience	Find strategies; Speak the same language; Rethink experience.
Gain knowledge	Inform yourself, look around	Know the target group; Inform yourself, look around.
Prevention	Selection of clients and projects	Anticipation
Provide structures	Working environment	Working environment
Explicit values -	Economy, Cooperation, Coherence and Quality	Quality, Communication, Cooperation and Control
Application results	Exchange and compensation due to office's reputation and network.	Exchange and permanence due to social recognition of the company.

Invariants

The nine invariant sub-categories entail codes regarding the organizational team, the design process, management, planning, the design context and stakeholders.

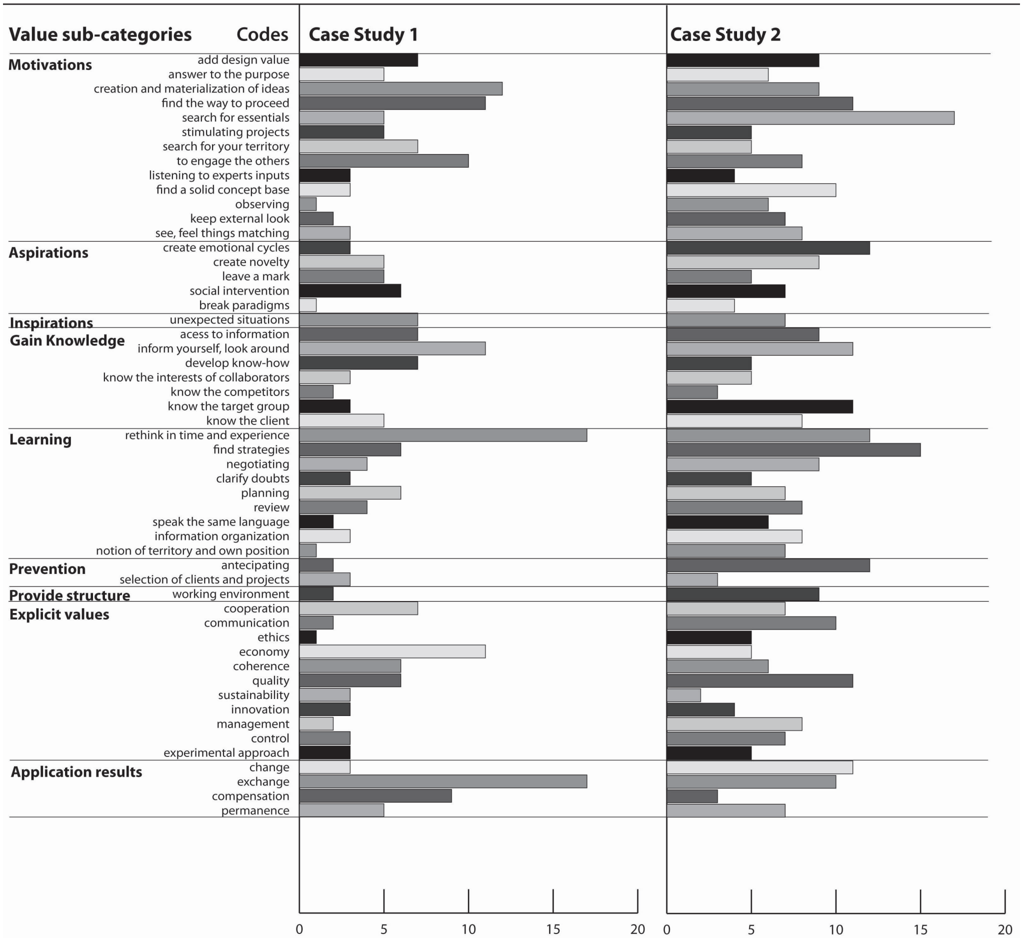


Figure 5.1. Overview of designers' *Value* sub-categories in the Graphic and Interaction design case studies

Variants

The design consultancies face common and different design management tasks. Each of these two groups has nine designers, with background such as Graphic and Multimedia design as described in Chapter 3 and 4. Each designer has a different allocation of *Value* due to specific design activities, aims and concerns. Analysis based on the comparison of three deviant interviews of Graphic designers with different tasks and functions is described. Each of these three designers shows a different allocation of *Value* reflecting each one permanent design activities and individual preferences (Figure 5.2).

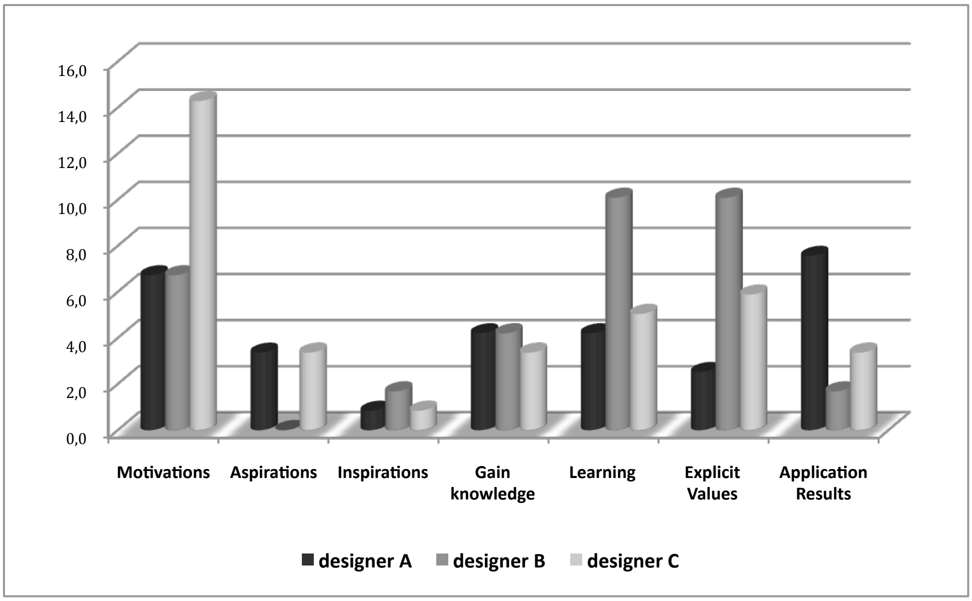


Figure 5.2. Three designers allocation of categories of *Value*

Designer A is a permanent collaborator, whose main activities are book covers for publishers. This permanent work demands a quick response due to time to market pressure. This designer refers *Value* codes not referred by others, such as: the importance of *having the necessary information in the beginning of a project* but also being *well organized*; the need to *do not spend too much time doing the same thing*. Designer B is also a permanent collaborator focused on production. This designer refers specific *Value* codes such as: *know the interests of collaborators* and *guarantee the concept solution in the final result*. Designer C is a non-permanent collaborator that handles a variety of projects. This designer refers specific *Value* codes such as: *speak the same language* and *know the competitors*.

Summary

The translation of the Lean Principle of *Value* in design, brings new aspects such as categories of *Value* for designers derived from Studies I and II. The concept of *Value* is understood as an economic measure but also as what designers *Value* in their activity. The designer or design team perceives the creative recognition of a *Value* system related to the design subject during each design processes. These *Value* dimensions are intended for user *Value*, product success and have significant importance for structuring the design process. The analysis showed that designers' *Value* assessment is dynamic, frequently changing according to the anticipation of client/user needs, the design context and specific situations. Designers' *Value* systems are design discipline, culture, design environment and design problem context related.

The categorization system was presented to the panel of evaluation for feedback on a Likert scale based questionnaire (see Appendix B). Results show an agreement of 81,4% with the categorization system. Average per sub-category of codes goes from 1 cluster of 3,92 and 8 clusters over 4 to 4,4 (1-5). The average of importance attributed to the nine sub-categories is 5 (1-6), seven categories over 5 and two of 4,3 and 4.7. Designers suggested grouping the nine categories into as few as proposed. *Value* for designers unfolds in three main categories:

- **Actions** – this category entails actions based on motivation, aspiration, inspiration, learning, gaining knowledge, prevention and providing structure.

- **Value(s)** - this category entails explicit *Value(s)* thought as citizens and professionals living in society.
- **Application results** - this category entails the mental and physical actions of recognition, permanence, compensation and opportunity to introduce change.

The inter-rater reliability test shows an agreement of 79% of second level and codes categories. Disagreement relates to 10% of combination of codes and sub-categories and overlapping between the sub-categories of *learning, explicit Value(s), gain knowledge* and *motivations.* For 11% of the combinations the researcher did not find alternatives.

As the studies advanced it was observed that the answers to the research sub-questions were many times dependent on the investigation of dimensions of analysis of other Lean Principles and *MUDA*. Therefore, every time results are described in other sub-chapters, such indication is made in the table of the research sub-questions and results. Table 5.2 sums the results of the research sub-question.

Table 5.2. Overview of research sub-questions and results so far

<table>
<tr><th>Lean Principle</th><th>Dimensions of analysis</th><th>Research sub-questions</th><th>Results</th></tr>
<tr><td rowspan="4">Value</td><td>Identify Value from designers perspective</td><td colspan="2">What do designers’ Value in design across disciplines?</td></tr>
<tr><td colspan="2">Studies I and II based on interviews</td><td>Categories of Value for designers</td></tr>
<tr><td>Identify how designers deliver Value in action</td><td colspan="2">How do designers deliver value to the design process and design results in design meetings?</td></tr>
<tr><td></td><td colspan="2">Described in 5.1.4 Investigating Pull in design.</td></tr>
</table>

5.1.2 Investigating *Value Stream* in Design

In this sub-chapter two studies are described: Study IV, that reports the identification of categories of designers' approach; and the parallel study introduced in Chapter 4 (4.5) that presents results from a teaching experience with the Industrial design graduating students from case study 5.

Categories of designers' approach

At this stage, the identification of the characteristics of designers' approach comparable to the Lean principle of *Value Stream*, was seen as an initiative that could lead to the identification of variants and invariants of what designers *Value*. The idea of this study was to investigate the *Substance* (from Latin substantia *'being, essence'*, from substant- *'standing firm'*, from the verb substare) of designers' approach. The small medium enterprise of interactive design solutions was the appropriate environment to study designers with different backgrounds and approaches sharing a challenging and innovative design environment where, *'Their job will be to give substance to new ideas while taking away the physical and organizational foundations of old ones.'* (Jones, 1970, p 33).

The Study IV reports results from a within-case analysis and provides insights on the characteristics of five designers with different backgrounds and one non-designer sharing the same working environment and contributing to the creation of interactive design solutions. The content of the six interviews were analyzed with the purpose of identifying what characteristics ascertain common and different approaches to design. The structure that emerged from the data was compared to the literature and showed similarities and theoretical insights with the Aristotle categories of substance (Aristotle, 1986, 1994, Portuguese translations). A categorization system of six main categories encompassing categories of substance to which sub-categories were addressed, derived from the results (Table 5.3).

Table 5.3. Categories of designers' approach

Categories	Categories of Substance (Adapted from Aristotle)	Sub-categories
Environment	*Place*	Structure, Values, Vision
Team	*Relation*	Role, Collaboration, Communication
Designer	*Essence*	Purpose, Concerns, Values, Type of problems
	Passion	Motivation, Emotion
Management	*Time*	Planning, Happening, Decision
	Situation	Client, Resources, Complexity
Process	*Quantity*	Design elements, Design tools
	Quality	Procedure, Strategy, Finding direction, Flow, Solution conceptualization, Solution representation, and Solution materialization
Performance	*Habit*	Learning processes, Cognitive processes, Attitude
	Action	Cognitive retrieve mechanisms, Heuristics

Study IV illustrates common, partially shared and distinct aspects of designers' approaches. Although the data entail a small sample, the content and distinctive character of each interviewee makes it a suitable piece of knowledge for the identification of variants and invariants of designers' approach. Categories are further described.

Invariants

The six categories are invariants of designers' approach across the six interviews. Figure 5.3 shows the incidence of each sub-category. The sub-categories of *Design problems* and *Cognitive retrieval mechanisms* emerged from data as the most shared and prevailing invariants across the interviews, followed by *Structure* and *Value(s)*.

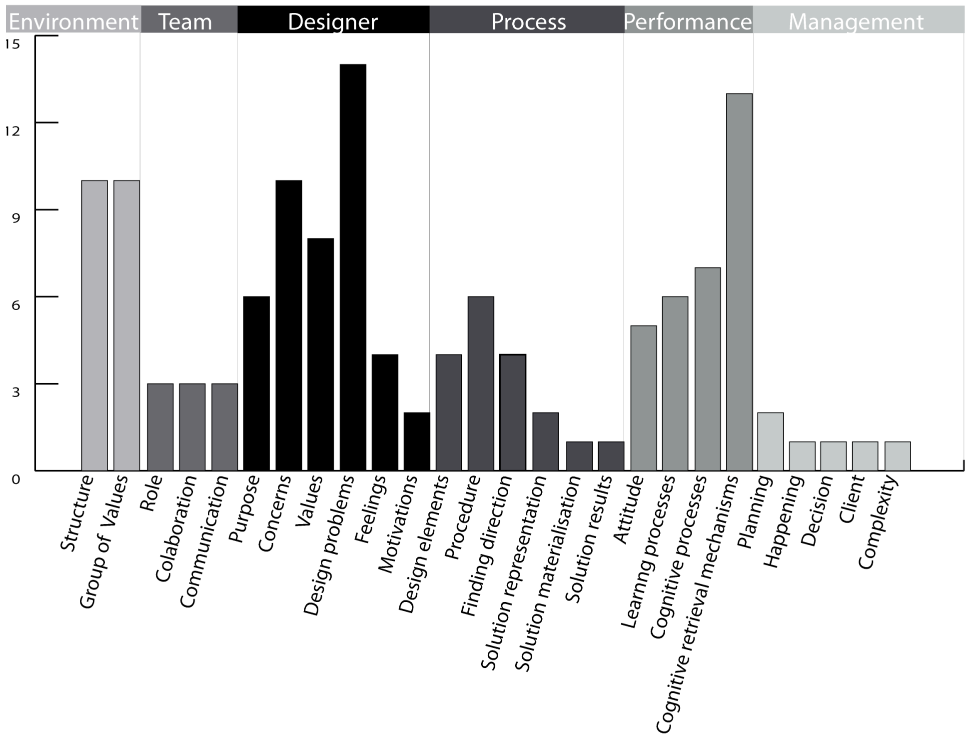


Figure 5.3. Invariant sub-categories to each one of the main dimensions (absolute numbers)

Environment - The category *Environment* entails the category of substance, *Place,* and addresses the working place and its environment characteristics, cultural *Value(s)* and issues of a broad and societal sense. Invariants regard two sub-categories: *Structure*, in codes such as, *Horizontal approach to people*, *Challenging company*, *Space to give and exchange ideas and do a good work*, *Personal accomplishment in teamwork*, and *Keep the person active and aware*; and *Value(s)*, in codes such as, *Liberty of saying, Freedom to think and explore, Opinion recognition*, *Individual reliability* and *More engagement.*

Team - The category *Team* entails the category of substance, *Relation,* and addresses the teamwork and designers' individual and team roles. Invariants regard three sub-categories: *Team role,* in codes such as, *Add suggestions as user and professional, Competence recognition* and *Contribute to define the value of the result*; *Collaboration*, in codes such as, *Sharing, Personal and team engagement, Converge to the same objective*; and *Communication,* in codes such as, *Willing to listen, Discussion* and *Focus.*

Designer - The category *Designer* entails two categories of substance:

The category *Essence,* addresses designers' essential aspects such as, purposes, concerns, *Value(s)* and the type of design problems they deal with. Invariants regard four sub-categories: *Common purposes,* in codes such as, *Knowing the problem context, Project objectives and target group, Learning from the process, Quality and reliability of final result*; *Concerns,* in codes such as, *Project feasibility*, *Knowing each one team role*, *Planning* and *Solution improvement*; *Value(s)*, in codes such as, *Cooperation, Experience, Integration, Inclusion* and *Simplicity*; and common *Design problems,* in codes such as, *Structuring the problem or the solution* and *Situations that influence the work of all.*

The category *Passion,* addresses feelings and motivations that include emotions and beliefs. Invariants regard two sub-categories: Designers share contrasting *Feelings,* in codes such as, *Enthusiasm* and *Tiredness*, and *Motivations,* in codes such as, *Learning* and *Personal interest* for projects.

Process - The category *Process* entails two categories of substance, namely, *Quantity* and *Quality* that address design elements, methodology and solution. Examples of invariants regard three sub-categories: *Design elements,* in codes such as, *Alphanumeric representations* and *Structural relations; Finding direction,* in codes such as, *Mental scheme*; and *Solution representation,* in codes such as, *Mental and Physical sketch.*

Management - The category *Management* entails two categories of substance:

The category *Time* relates to aspects of planning, happening and decision in the design process. Example of invariants regard three sub-categories: *Planning,* in codes such as, *Know planning information from the project manager*; *Happening,* in codes such as, *Not possible to have everything clearly defined early*; and *Decision* in codes such as, *Commit to the decision on the final solution.*

The category *Situation* relates to aspects of the problem situation, such as client, resources and complexity. Invariants regard three sub-categories: the *Client*, in codes such as, *Inform on project feasibility*; *Resources*, in codes such as, *Cope with available elements and persons*; and *Complexity*, in codes such as, *Complex projects that require more work and time in structuring*.

Performance - The category *Performance* entails two categories of substance:

The category *Habit* relates to permanent actions of designers. Examples of invariants regard three sub-categories: *Attitudes* in codes such as, *Being positive, being flexible, Experimenting, Clarify doubts* and *Open mind; Learning processes* in codes such as, *Learning through mistakes, Reuse of knowledge and solutions;* and *Cognitive processes* in codes such as, *Thinking, Analysis* and *Imagining.*

The category *Action* relates with designers transitory actions to solve more persistent and difficult problems. These actions relate to the sub category of *Cognitive retrieval mechanisms.* Examples of invariants were found in codes such as, *Awareness, Questioning, Proposing, Asking what is missing, Risk assessment, Opportunity recognition, Control recognition, Limits recognition* and *Give time.* Designers share several cognitive retrieve mechanisms to improve personal and solution performance.

Variants

In this study, variants relate to statements clustered in a same sub-category but whose codes show variation of meaning and perspectives. Variants are dominant in three main categories namely, *Designer, Process* and *Management* as shown in more detail in Figure 5.4. A thorough analysis of the three categories is described. Other sub-categories of lower incidence but of evident distinction between designers' approach are given as example. Variants such as the sub-categories of *Client* and *Solution conceptualization* emerge aligned as the most prevailing variants.

These aspects relate to designers' different interests in solving parts of the same general design problem and specific level of concern with the final result. Lower incidence of variant codes per sub-category relate to the working structure or clearly divergent behavior.

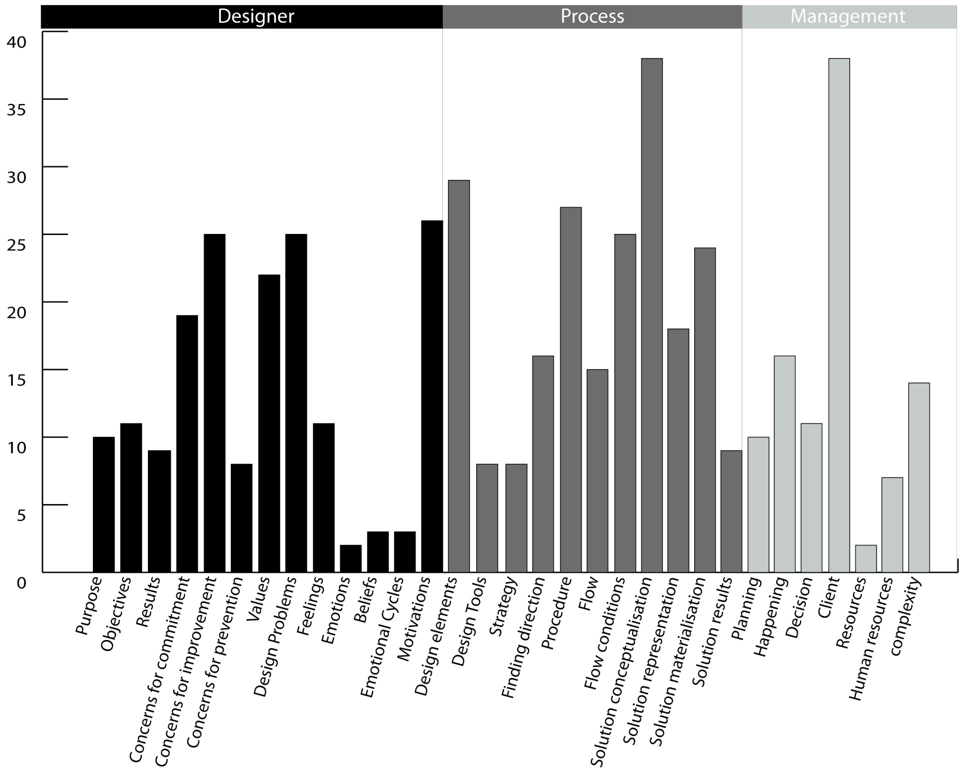


Figure 5.4. Variant sub-categories in three dominant dimensions (absolute numbers)

Designer

The category *Designer* has the sub-categories of *Motivations, Design problems and Concerns for improvement* as the sub-categories with the most variant codes. Variant design problems relate to: *structure* issues such as, *Functional, Conceptual, Problem and Communication Structure;* and *Context* issues such as, *Context of experience, Identification of opportune technology* and the *Interaction problem*. Engineering-based designers (Software architecture, Mechanical and Environmental engineering) purposes and concerns hold on pragmatism, technology, testing and performance and Design/Art-based designers (Graphic and Industrial design, and Interactive Arts) and the non-designer (Literature) hold on aspects of communication and experience in final results. The designer with Environmental engineering/Interactive Arts background shares both due to his extended knowledge, interests and skills. Design/Art-based designers are motivated to think beyond project objectives and goals and see things matching. Engineering-based designers are motivated to see things working.

Process

The category of *Process* has major incidence of variant codes in sub-categories such as, *Solution conceptualization, Design elements, Procedure, Flow conditions* and *Solution materialization.* Designers differ in several aspects of the process. Engineering-based designers and the non-designer (Software architecture, Mechanical engineering, Literature) regard tangible design elements while Design/Art-based designers (Graphic design, Industrial design) regard tangible and intangible design elements. Engineering-based designers have more straightforward procedures, while Design-based designers and the non-designer (Literature) have similar procedures. Process procedures relate to own purposes, project path and the client. The designer with a Software architecture background deals less with uncertainty, while the other designers deal more with uncertainty and recognize a process of choice based on the feeling of balance toward the final result. Interviewees share design tools to solve common problems. Other use of tools is dependent on person's competence and domain. Table 5.4 illustrates variant codes per sub-category across the interviewees with the following background discipline: Software architecture (S), Graphic design

(G), Literature (L), Mechanical engineering (M), Industrial design (I) and, Environmental engineering and Interactive arts (EI).

Table 5.4. Examples of sub-categories and codes for the category of *Process*

Sub-categories	**Interviewees**					
Design elements	**S**	**G**	**L**	**M**	**I**	**EI**
Hardware and software components	▨			▨		
Digital visual representations		▨	▨		▨	
Narrative	▨	▨	▨			▨
Time and scale, Interaction, action/reaction, audio		▨			▨	▨
Movement and relative dimensions		▨		▨	▨	▨
Finding direction	**S**	**G**	**L**	**M**	**I**	**EI**
Know what will remain, the project mark, the project flame		▨				▨
Choice is based on priority, available elements, feasibility and importance		▨	▨	▨	▨	▨
Explore all the alternatives				▨		
Economical constraints		▨	▨			▨
Balance what we have, what we know, newness and public attraction						▨
Solution conceptualization	**S**	**G**	**L**	**M**	**I**	**EI**
See it as the best one	▨					
Have a 1st fuzzy vision, Immediate senses, perception of 1st characteristics		▨				▨
Identify immediate sensation on users 1st impression to assure attention		▨				
That people recognize themselves in the concepts, Use of metaphors			▨			
Number of units to build, Different options				▨		
What message to transmit, Theme, Approach to the theme		▨	▨		▨	▨
Feasibility of concept materialization, Usefulness of the concept						▨
Solution materialization	**S**	**G**	**L**	**M**	**I**	**EI**
Effective communication of tangible and intangible effects (i.e. feelings)		▨	▨		▨	▨
Performance, Protect hardware from environment agents	▨			▨		
Color, Aesthetic, Light, Sound, Materials		▨			▨	▨
Budget			▨	▨	▨	
Being specific, precise in solution materialization, Detail		▨				
Being aware of the change in ideas when thinking in pragmatic terms						▨

The approach to *solution conceptualization* differs in the same relation as designers' *purposes*. *Mental and physical representations of solutions* are more frequent among Design/Art-based designers and the non-designer. Engineering-based designers have a more pragmatic approach to *solution materialization*, while Design/Art-based designers are more concerned with the characteristics of the *final result appearance* and *the experience* than the other designers.

Management

The category of M*anagement* has major incidence of variant codes in sub-categories such as, *Client, Happening, Complexity* and *Decision.* Design-based designers and the non-designer are more concerned with building relations with the client, while Engineering-based designers have a more pragmatic approach to the clients. Managing complexity, one of the Lean Thinking types of *MUDA*, in design relates to differences in aspects such as, *methods, motivations, priorities, timings* and *unpredictability.*

All the interviewees experience unpredictable situations with a surprise and challenge effects that compelled them to change or review. For example, the software designer is comfortable with *not having to make decisions*, while the graphic designer needs to *have the control of decisions*, as he was the leading designer of projects.

Variants found in the categories of *Environment, Team and Performance* with management implications are worth of reference. For example, Design/Art-based designers show more diverging aspects regarding *motivations, gathering experience, opportunity to deliver innovation* and *contributing to the society and country evolution.* Individual roles differ in team.

Engineering-based designers are more focused in the materialization of projects while Design/Art-based designers have more interest in the project creative stage and characterization of the final result. The designers with Environmental engineering/Interactive Arts background and Mechanical engineering both share engineering-related paths of the process although with different *purposes.* The Graphic designer has a leading role in design management. Concerns regarding *attitudes* and *performance* also differ. Designers with background in Literature, Mechanical engineering and Industrial design cope with *pressure*, the Graphic designer and the Environmental engineering/interaction Artist work positively with *pressure* while the Software architect does not. These characteristics seem to relate with each one team role and individual profile. Table 5.5 illustrates variant codes per sub-category.

Table 5.5. Examples of sub-categories and variant codes for the category of *Management*

Sub-categories	**Interviewees**					
Planning	**S**	**G**	**L**	**M**	**I**	**EI**
Respect time	▨					
I'm not much structured in planning		▨			▨	
I plan to execute			▨	▨		
Periodic meetings to review and register deliverables and sales pipeline				▨		
Planning strategy to prepare the future, Be ready to review and reschedule						▨
Happening	**S**	**G**	**L**	**M**	**I**	**EI**
Be able to skip the plan	▨					
Perchance, time and words influence in having sudden ideas		▨				
Find something more interesting to substitute other, Find new things			▨			▨
Reformulate according to things that were not taken into account				▨		▨
Errors that turn into a good thing and you can take advantage of					▨	▨
Client	**S**	**G**	**L**	**M**	**I**	**EI**
Answer to client request/need	▨			▨		
Find approach to cope with types of client, project, client real wishes		▨	▨		▨	
Bother the client with questions for what he doesn't know the answer		▨	▨		▨	
Interpret and clarify client request, User as final user not the client		▨			▨	
Team with the client, empathy working in the same direction and bearing		▨			▨	
Manage client expectations		▨				▨
Mark necessary positions, Client aware of the experience value		▨				
Know what the client wants to say and to communicate			▨			
Complexity	**S**	**G**	**L**	**M**	**I**	**EI**
Difficulty in keeping method			▨	▨	▨	
Unpredictability of doing technological artisan					▨	▨
Manage expectations, workflow, deadlines, stress, priorities, significance		▨				
Colleagues resistance to corrections, Adjust details and finishing		▨				
Manage conceptualization with production phase, timings and suppliers					▨	
Lost of quality and rigor in complex situations					▨	

Designers also refer to cognitive processes that frame similar actions with different terminology. Examples of variants are, *Interpreting, Pursuing* for Design/Art-based designers, *Structuring, Restructuring,* are shared by the same designers and the non-designer, *Decomposing,* for Engineering-based designers. Design/Art-based designers and the non-designer share some *Cognitive retrieval mechanisms*, such as, *Perchance recognition* as well *Perception of sensations* from the *recreation of the solution*. They are concerned with *Recognizing quality* in *performance* and *results*. From the general results, variant characteristics are dominant as shown in Figure 5.5.

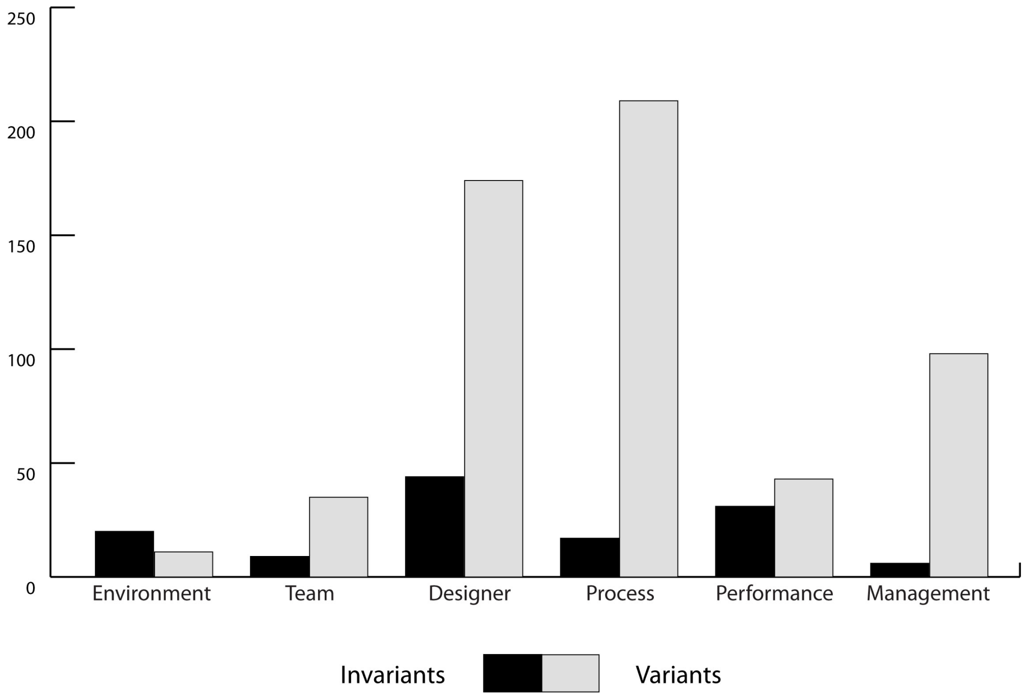


Figure 5.5. Incidence of variant and invariant codes to each dimension

The dominant dimensions of *Designer, Process* and *Management* show higher incidence of variants. The dimensions of *Environment, Designer* and *Performance* are the invariants with higher incidence that just prevail in the *Environment* category, which is understandable once the cultural *Value(s)* and structure of a company considerably frame the working environment. The dimension *Designer* is strong in both, variants and invariants. The dimensions of *Process* and *Management* show more discrepancy with a low amount of invariants and a high amount of variants. Intermediary features relating to sub-groups of designers (Design/Art-based designers, Design-based designers, Engineering-based designers) show shared sub-categories, as *concerns, values, design elements, problems* and *procedures.*

The study infers that Engineering-based designers do not concern final *solution appearance* so much, but its *functional performance* and differ from Design-based designers in the absence of some characteristics such as, *mental recreation of the context* and *users interaction experience.* These characteristics represent their concern with the communication of intangible results such as *feelings*, also shared by the non-designer and the Engineering/Art-based designer. In addition, each designer refers specific variants that relate directly with their background and *concerns*. In particular, the non-designer shows specific characteristics not shared with any other interviewee: misses *concerns* with *solution performance*; does not refer the *implementation of design*.

Results show that variants such as, *purposes, concerns, design elements* among others, comprise scopes such as, *Value* systems, cognitive structures and patterns of action, that characterize each designer approach making them varying in substance.

This inspiring study brought into evidence aspects such as: *Value* dimensions for designers, *Flow* aspects, *Pull* aspects, sources of *MUDA*, need for *MUDA*, that later inspired the elaboration of categories.

New actions and lessons learnt from a NPD experience

Results derived from the parallel study described in chapter 4 (4.5), show two emerging aspects of industrial design students' approach. New actions they had to perform (Table 5.6) to face the challenging assignment and the lessons learnt from this new product development (NPD) experience.

Table 5.6. Industrial design students' statements on new actions performed

Industrial design students' statements on new actions performed
'Search in nature and science, movements and experiences that could be found everywhere.' *'Searching for interesting movements, scientific principles and by looking at existing game principles.'*
"Most of the assignments at IDE solve a certain user problem. The design of a brainteaser does not really have a goal that gives a lot of direction to the design process. You have to search for "something", a puzzle element, but the assignment or user group does not give you a lot of leads. With a normal consumer product, there are often more things clear about the product and user needs.'; 'Identify the critical drivers.'
'Within this project we were searching more for inspiration, rather than a solution.'
'Physical phenomena gave inspiration for generating new ideas.'
'Go beyond internet search for competitor products, but visit shops and try the products, it gives an extra dimension.'
'The best way for me to create something new and inventive was using associative thinking. Since a brainteaser often requires an innovative feel and look I found it easier to think of problems by using pictures and video to invoke thoughts. Normally I'm using my common sense to create logical solutions for smaller and simpler improvements and ideas.'; 'Know a lot of examples to get a kind of "puzzle thinking.'
'I needed to dig up an old method. Looking at other design and try and see if you can use these designs in a whole new field.'
'Working models and user research to investigate if the users like the concept.'

The new actions students had to perform relate to *the difficulty identifying drivers*, in setting the path of *Flow*, learning *how to make own choices*, improving the *feeling of competence,* looking into *unusual sources of inspiration*, for effective *Value* judgment, and *adapt their usual structured method to each one own way of feeling and thinking the design process* for more flexibility of the design approach, and its course of actions which relate to the Lean Principle of *Value Stream.* Students recognized some lessons learnt, *knowing more about themselves as designers*, more specifically their strengths and weaknesses in *identifying the crucial drivers of a solution instead of assuming given ones*, exploring the possible directions to follow and anticipating its consequences.

As a final aspect, students referred the lessons learnt within the new product development experience, indicating the benefits, and what should be improved

(Table 5.7). Students found more about each one own way of designing and felt more confident. Choosing the adequate process to a design assignment seems to be dependant on the nature of the design problem and fitting procedural flexibility.

Table 5.7. Industrial design students' statements on lessons learnt

Lessons learnt	Students' statements
Benefits	• **Usefulness of structured methods as usual procedures** • **Discovering own design way** • **Improving feeling of competence**
	'If I would not have followed the main steps of the process, I might still be working on ideas in the idea phase. The usual procedure showed me that structure was needed to work with such a difficult and broad topic.' *'I found that in this project I just need my own way, and that gave me way more confidence in my design skills.'* *'I realized where my strengths and weaknesses lie in the design process more than in any other project.'* *'I learnt more about designing and myself.'*
Future Improvement	• **Rethink the choice of direction stage in the design process** • **Explore several directions before choosing one**
	'Within a "normal consumer product" design process, the direction is chosen after the market directions are explored. Within this process however, the choice of a direction would do nothing but limit the inspiration for the possible puzzles. We had to look in each direction in order to find a good puzzle in one of those directions.'

Figure 5.6 illustrates the streams in which a designer can move and adapt his/her approach to a design problem circumstances. Students uncovered an important need in order to keep the control of the design process and personal satisfaction: freed from a structured process without loosing its kernel for a satisfying and more innovative result. With this learning experience students faced increasing awareness of the fact that the product design and development process is not rigid and should be adaptive, making it more responsive and flexible to the required type of innovation.

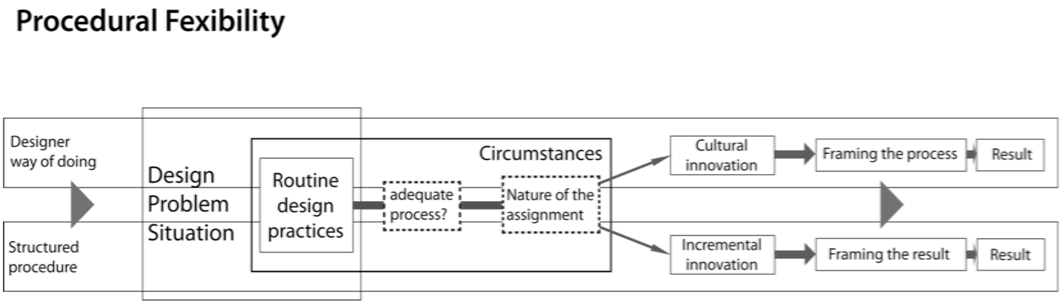


Figure 5.6. Influence of the nature of the assignment on designers' choice for a dominant stream of actions: the designer's own way of doing or a learnt structured procedure

Summary

Both studies were relevant to identify streams of action, and variants and invariants of designers' approach comparable to the Lean Principle of *Value Stream.* Study IV was based on data from a multi and transdisciplinary design environment with complex design processes that asks for newness of interaction design solutions. The study derived from the teaching experience is based on a design assignment that also asked for newness and invention. Such design processes are rich in situations that designers do not know how to cope with. Therefore, both studies are based on the appropriate data for the identification of categories of design approach and procedural flexibility in difficult situations. These studies show higher complexity in the assessment of the Lean Principles *Value* and *Value Stream*, that the previous interdisciplinary studies. *Value Stream* in design is not just a set of actions but also a course of adaptive actions in coping with positive and negative effects of sources of *MUDA.*

The assessment of categories of designers' approach derived from Study IV. This categorization system was presented to the panel of evaluation for feedback on a Likert scale based questionnaire (see Appendix B). Results show an agreement of 86,6% with the categorization system. Average of clusters of sub-categories per dimension is 4,3 (1-5) all over 4. The average of importance attributed to the ten categories is 5,2 (1-6), nine categories over 5 and one of 4,6.

The inter-rater reliability test shows an agreement of 94% of first and second level categories. Disagreement relates to overlapping between the categories of *designer*, *management*, *team* and *process*. Table 5.8 adds results to the research sub-questions.

Table 5.8. Overview of research sub-questions and results so far

Lean Principle	**Dimensions of analysis**	**Research sub-questions**	**Results**
Value	Identify *Value* from designers perspective	*What do designers' Value in design across disciplines?*	
	Studies I and II based on interviews		Categories of Value for designers
	Identify how designers deliver *Value* in action	*How do designers deliver value to the design process and design results in design meetings?*	
		Described in 5.1.4 Investigating *Pull* in design	
Value Stream	Identify characteristics of designers' approach	*Do designers sharing the same design environment show the same design approach characteristics?*	
	Study IV based on interviews		Categories of designers' approach Procedural flexibility
	Mapping *MUDA* in design	*How to map MUDA in design across different design disciplines?*	
		Described in 5.1.5 Investigating *MUDA* in design	

5.1.3 Investigating *Flow* in Design

From the previously described Study IV, codes on *Flow breaks* and *Flow conditions* derived from the analysis of interviews. Table 5.9 illustrates variant codes per sub-category across the six interviewees with the following backgrounds: Software architecture (S), Graphic design (G), Literature (L), Mechanical engineering (M), Industrial design (I) and, Environmental engineering and Interactive arts (EI).

Table 5.9. Examples of codes regarding *Flow* breaks and *Flow* conditions

Flow breaks	**S**	**G**	**L**	**M**	**I**	**EI**
Dependence on others use of tools		▨				
Communication failure in transmitting what is intended to be done		▨				
Delay		▨				
Entropy		▨				
Use of own representation tools that do not allow seeing it working		▨				
Boring work, lack of motivation		▨				
Having too much time, getting tired and dispersed		▨				
Knowledge dispersion due to newness of the area		▨				
Difficulties in communicating my vision		▨				
Colleagues resistance to correct, adjust details and finishing		▨				
Confusion			▨			
Interruptions				▨		
Clients that ask more than was determined				▨		
Colleagues not willing to communicate				▨		
Changing mind set context				▨		
Not being in the right mood				▨		
Do not have all the team persons when is necessary				▨		
Switch task				▨		
Task priority change, change priority context,				▨		
Do not think enough about what has to be done				▨		
Lack of control				▨		
Unable to concentrate		▨		▨		
Absence of essential elements in the assignment					▨	
Loss of quality and rigor in complex situations					▨	
Neglect users or other type of validation					▨	
Projects not well estimated					▨	
Difficulty in managing timings and type of suppliers					▨	

Creating new solutions faster than the company can absorb technology						▨
Users dissatisfaction						▨
Something that commercially did not work						▨
Saturation	▨		▨			
Cannot finish the project or give it the expected end, difficult processes					▨	▨
Dispersion				▨		▨
Working too many hours, getting tired and unfocused	▨	▨	▨	▨		
Issue you cannot solve, getting stucked, forget the scope	▨	▨		▨		
Harmful pressure	▨			▨	▨	
Flow conditions	**S**	**G**	**L**	**M**	**I**	**EI**
Need to refuge to distress	▨			▨		
See things working	▨			▨		
Need to experiment		▨				
Step back		▨				
Leave it for a while, give a break, have distance, take a coffee	▨	▨				
Being fast	▨					▨
Go with the flow						▨
Think about it later, how to do it better	▨	▨		▨		
Have distance, look with other eyes, have a different perspective, consider others perspective, think differently			▨	▨		▨

From these variant codes *Flow breaks* seem to derive from interdependencies such as: *miscommunication, using inadequate means, delays, missing motivation, losing focus, knowledge dispersion, difficulty to express ideas, missing colleagues collaboration, interruptions, excess of work, mood influence, absent collaborators, switching tasks and priority, lack of control, absence of essential elements for the development of the design, diminished quality and rigor, neglecting validation, under estimation of costs, time and suppliers management difficulties, difficulty to materialize advanced ideas, users and clients' dissatisfaction, possible commercial failure*. *Flow breaks* relate to each one *concerns*, *teamwork* issues, circumstances of too much or too less workload.

Flow conditions relate with each one *motivations*, need for isolation or exchange of different perspectives. *Flow* conditions are twofold: *slowing down* – designers take a rest and look for situations to lighten up, leave the work for a while creating some distance, ask for others opinion, think differently to later have a different perspective; *speeding up* – performing faster and seeing things working to keep motivation and remain in *Flow*. This analysis shows *Flow* characteristics but also sources of *MUDA* in design, such as interdependency, information transfer and exchange, and *MUDA* (waste) positive effects.

Categories of drivers of *Priority Value* for decision-making

The purpose of Study V was to investigate not just what do designers *Value* but what drives designers to identify priority towards decisions. The study reports findings based on the analysis of 16 interviews transcripts, four per each case study in Graphic design (G), Architecture (A), Interaction design (I) and Mechanical engineering (M).

Findings derived from this study are proposed as categories of drivers of *Priority Value* for decision-making in design across disciplines, namely, *Emotion, Intuitive, Rational, Experience and Constraint-based* priorities (Table 5.10). These drivers integrate designers' *Value* systems as components of *Value* choice, and constitute patterns of thinking and acting in the process of delivering *Value* to final results with a de/activation function of *Flow.* Such drivers determine action or inaction, *Flow conditions* or *Flow breaks.* These characteristics encompass designers' priorities as individuals with design-oriented *Value* systems for solving issues that derive from the context of the design situation. Sub-categories show the content of the driver of *Priority Value* through expressions or succinct words related to descriptions of designers' thinking and acting while taking decisions. Relevant aspects which determined decision-making in design reported in literature were also found and organized into a categorization system: experience, use of information from previous projects, intuition, culture, predicted or unforeseen elements of risk, chain of known and unknown design constraints, unknown design variables and design intentions (Beheshti, 1993). The five main categories can be present in the same situation, and one, or a set of some can assert priority of *Value* judgment towards decision. The analysis of frequency revealed invariant categories of drivers of *Priority Value* across disciplines. The codes frequency is presented in relative numbers based on percentage.

Table 5.10. Categories of drivers of *Priority Value* for decision-making across four case studies

Main-categories	Sub-categories	G	A	I	M	St.D	Mean
Emotion-based	Interest, like what I do	5,13	2,68	5,71	6,14	1,54	4,92
	The sensations to transmit to people	1,92	1,34	6,94	0,00	3,03	2,55
	Feeling of uncertainty	1,92	2,01	0,82	1,81	0,56	1,64
	Start seeing results	2,56	2,68	2,04	3,61	0,65	2,72
	Challenging opposition	3,21	1,34	2,04	0,72	1,06	1,83
	Personal and team emotional evaluation along the process	3,85	2,01	6,12	2,53	1,83	3,63
Total		***18,59***	***12,08***	***23,67***	***14,80***		
Intuitive-based	Feeling that something is wrong	1,28	1,34	1,63	0,72	0,38	1,24
	Feeling certainty about a choice without argument	3,21	2,01	4,49	2,89	1,03	3,15
	Feeling of certainty in changing priorities	0,64	0,67	1,22	1,44	0,40	1,00
	Action driven experimentation	4,49	3,36	2,04	3,97	1,06	3,46
	Individual or external sources of inspiration	3,85	6,71	6,53	7,22	1,52	6,08
Total		***13,46***	***14,09***	***15,92***	***16,25***		
Rational-based	Know-how, specific knowledge	8,97	7,38	5,31	5,78	1,67	6,86
	Project management	4,49	3,36	3,67	3,25	0,56	3,69
	Design purpose, goals and direction of procedure towards the solution	10,90	9,40	8,98	7,58	1,36	9,21
	Ethics	2,56	3,36	3,27	1,08	1,05	2,57
	Users satisfaction	0,00	2,68	4,49	1,08	1,96	2,06
	Design problem context, situation and circumstances	4,49	6,71	3,27	2,53	1,83	4,25
	Redo, fine-tuning or reviewing	4,49	3,36	2,04	3,61	1,01	3,37
	Undeveloped Knowledge	0,00	0,67	1,22	2,17	0,92	1,02
Total		***35,90***	***36,91***	***32,24***	***27,08***		
Experience-based	Framed design choices	7,05	2,01	2,04	2,17	2,49	3,32
	Evaluation and association with results and processes from the past	2,56	4,03	3,27	2,89	0,63	3,19
	Looking for references	3,21	4,70	2,86	1,81	1,20	3,14
	Open mind for new solutions	2,56	2,68	2,45	3,25	0,35	2,74
	Experiencing the design situations, Foreseeing the experience through simulation	1,28	2,01	2,86	6,14	2,14	3,07
	Foreseeing difficulties	1,28	2,68	2,45	3,25	0,83	2,42
Total		***17,95***	***18,12***	***15,92***	***19,49***		
Constraint-based	Time limitation	3,85	2,68	2,86	5,78	1,42	3,79
	Financial conditions	2,56	4,70	1,63	3,97	1,38	3,22
	Technology conditions	2,56	2,01	2,86	7,58	2,58	3,75
	New policies limitations	0,00	2,68	0,00	0,00	1,34	0,67
	Client restrictions	4,49	4,03	2,86	5,05	0,93	4,11
	Cultural conditions	0,64	2,68	2,04	0,00	1,24	1,34
Total		*14,10*	*18,79*	*12,24*	*22,38*		

In the following the definition of each main category is described supported by an example of the selected statements.

Emotion-based priority

Emotion-based Priority Value emerges when decisions are made upon the expression of arguments based on feelings regarding the circumstances, mood or in relation to others. Sub-categories entail issues related to *Motivation*, *Communication*, *Uncertainty*, *Seeing Results*, *Challenging Opposition* and *Emotional evaluation*. An example of statement from the Interaction design case study is given to the sub-category of *Sensations to transmit to people*:

> *'Interaction, the initial part, the really raw part, what you feel in your guts, the sensation I want others to feel much before thinking.'*

The statement shows one *emotion-based Priority Value*, *'the sensation you want others to feel'* for the creation of design solutions.

> *'Emotions are inseparable from and a necessary part of cognition. Everything we do, everything we think is tinged with emotion, much of it subconscious. In turn, our emotions change the way we think, and serve as constant guides to appropriate behavior, steering us away from the bad, guiding us toward the good.'*
>
> Donald Norman, 2004. *Emotional Design*, p. 7

Intuitive-based priority

Intuitive-based Priority Value emerges when decisions are made upon the expression of arguments based on the ability to understand something immediately, without the need for conscious reasoning. Sub-categories entail *issues related to Risk*, *Un/certainty*, *Priority*, *Experimentation*, and *Sources of inspiration*. An example of statement from the Architecture case study is given to the sub-category of *Action driven experimentation*:

> *'For example, when we visit the terrain in the beginning of the project, the initial idea we might have doing this visit is the most important one,*

> *some people have this idea and I think it is so much important as the opposite, living there for 2 or 3 days and understand how things work, but that first impact is important.'*

The statement shows the iteration between the above mentioned *intuitive-based Priority Value, 'the initial idea we might have doing this visit'* and the *experience-based Priority Value* of *Experiencing the design situation, foreseeing the experience through simulation, 'living there for 2 or 3 days and understand how things work'*. A set of drivers determines priority towards a solution.

> *'Much of the human behavior is subconscious, beneath conscious awareness. Conscious comes late, both in evolution and also in the way the brain processes information; many judgments have already been determined before they reach consciousness.'*
>
> Donald Norman, 2004. *Emotional Design*, p. 11

Rational-based priority

Rational-based Priority Value emerges when decisions are made upon the expression of arguments based on conscious reasoning and logic. Sub-categories entail issues related to *Know-how, Project management, Design goal* and *Procedure, Ethics, Users, Design problem context, Fine-tuning* and *Undeveloped knowledge.* An example of statement from the Graphic design case study is given to the sub-category of *Design problem context, situation and circumstances:*

> *'I try to fully understand the information they passed on to us and which will be our guideline. It's just like a casting, when you are doing a casting for a commercial you have to know exactly what you want. We have to know exactly what kind of image we'll use, what font we'll use, what is the context, what is the epoch...several things like these.'*

The statement shows the iteration between a set of drivers, the above mentioned *rational-based Priority Value, 'what is the context, what is the epoch'*, and *Design purpose, goals and direction of procedure* as the *Priority Value(s)* steering designer' thinking and acting, '*We have to know exactly what kind of image we'll use, what font we'll use'*.

Experience-based priority

Experience-based Priority Value emerges when decisions are made upon the expression of arguments based on practical contact with the subjects and observation of facts or events that derive from or lead to mature knowledge. Sub-categories entail issues related to *Framed design solutions*, *References*, *Association with results from the past*, *Open mind*, *Foreseeing the experience.* An example of a statement from the Interaction design case study is given to the sub-category, *Experiencing the design situations, foreseeing the experience through simulation:*

> *'My process is different and it's related to people's experience with things like: going in, coming out, touch, look, check the physical interaction, where are the eyes, where the body stands, etc. After considering all these experience features I also make sketches and think about the project's aesthetics.'*

The statement shows the iteration between a set of drivers, the above mentioned *experience-based Priority Value*, *'people's experience with things like: going in, coming out, touch, look, check the physical interaction, where are the eyes, where the body stands'*, and the *rational-based Priority Value* of *Know how, specific knowledge*, *'After considering all these experience features I also make sketches and think about the project's aesthetics'.*

> *'Treat life as one big experiment and you'll start building a framework for continuous learning. And having a learning organization is part and parcel of a culture of innovation. The experimenter helps keep the organization fresh and is willing to take calculated risks. Trace the history of any great innovation and chances are you'll find the footprint of an experimenter.'*
>
> Tom Kelley, 2006. *The ten faces of Innovation*, p 65

Constraint-based priority

Constraint-based Priority Value emerges when decisions are made upon the expression of arguments based on the limitations and conditions that reframe the state of affairs. Sub-categories entail issues related to *Time, and new policies limitations,* and *technology, financial, client and cultural conditions.* An example of a statement from the Mechanical engineering case study is given to the sub-category, *Technological conditions:*

> *'Basically you start listening to the client first, in the end you are going to build something that he needs or wants and hopefully pays for. On the other hand, robotics is the state of the art and that is a key factor. Robotics depends on a lot of sensory parts, which is a specific area with a lot of new inventions made weekly that you want to try, to build, to see because it runs faster…if you can use these kind of sensors in this kind of robotics you can do away more.'*

The statements show the iteration between a set of two drivers constraint-based *Priority Value(s)*, the above mentioned *Technological condition*, '*if you can use these kind of sensors in this kind of robotics you can do way more*' and *Client conditions*, '*in the end you are going to build something that he needs or wants and hopefully pays for*'.

A more detailed analysis show variants and invariants of drivers of *Priority Value* across design disciplines revealing characteristics of design thinking and acting as well characteristics that distinguish each of the four case studies.

Invariants

The incidence of invariant categories of drivers of *Priority Value* across design disciplines is shown in Figure 5.7. *Rational-based Priority Value* is a dominant category across the four case studies, although with more emphasis in Architecture and Graphic design. *Emotion-based Priority Value* prevails in the Graphic and Interaction design case studies. *Constraints-based Priority Value* prevails in Engineering and Architecture. *Intuition-based Priority Value* has a similar incidence across the case studies. *Experience-based Priority Value* also shows similar incidence across the case studies decreasing in the Interaction design.

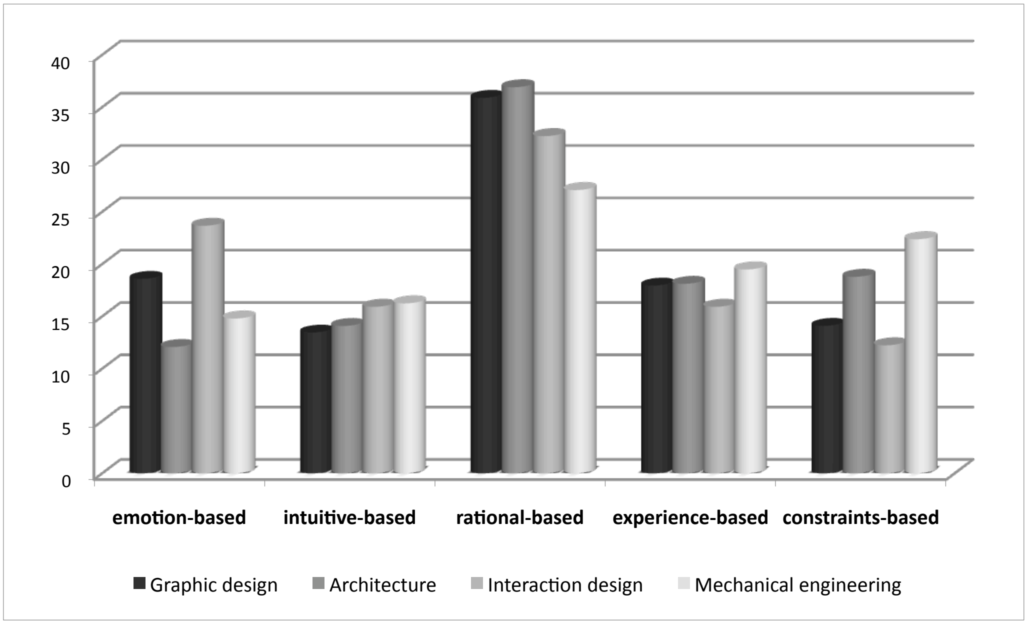


Figure 5.7. Incidence of driver of *Priority Value* per category across disciplines

The categories with highest variation among design disciplines are *Emotional*, *Constraints* and *Rational-based priority*. *Experience* and *Intuitive-based* priority categories show only a variation of 3%. *Intuition-based priority* shows higher incidence when the *Constraints* and *Experience-based priority* show higher incidence too (Mechanical engineering). *Emotion-based priority* is higher when *constraints* and *experience-based priority* are lower (Interaction design). *Rational-based priority* is higher when *emotion-based priority* is lower (Architecture). *Intuition-based priority* is lower when *experience* and *emotional-based priority* are even (Graphic design).

The general results show a dominance of 32% for *Rational based-priority*, quite similar rate of 17% for *Experience*, *Constraints* and *Emotion-based priority* and

15% of rate for *Intuition-based priority*. Exception to invariants regards five sub-categories.

Variants

Variants of designers' drivers of *Priority Value* for decision-making are distinguished across the four case studies. Rate analysis regards non-specific (0,00%), dominant (above 5%) and standard deviation (above 1,5) of sub-categories among the four case studies. Sub-categories of drivers of *Priority Value* that show 0,00% of rate in one or more case studies are shown in Figure 5.8. Such codes of drivers of *Priority Value* relate to the following sub-categories:

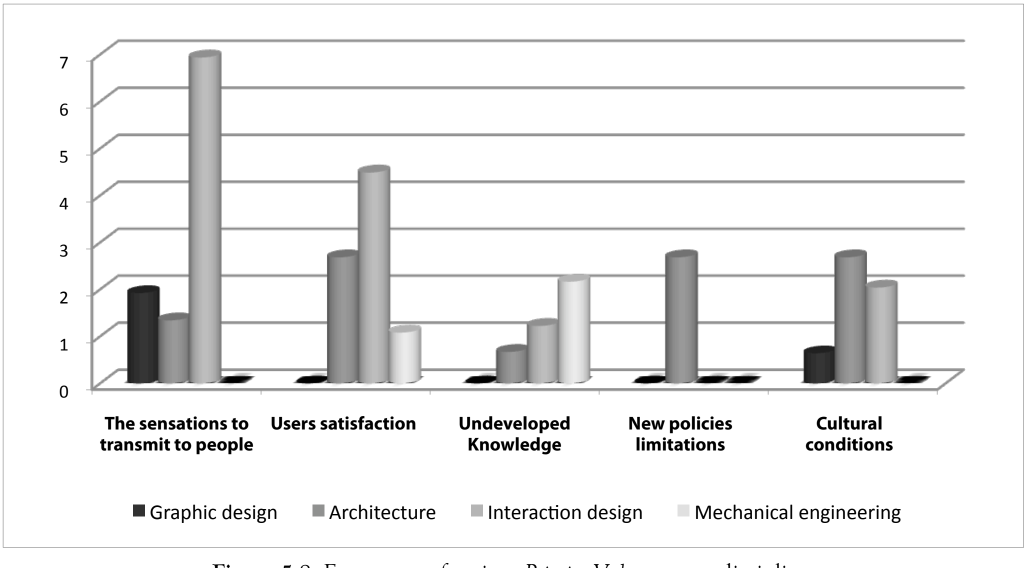


Figure 5.8. Frequency of variant *Priority Values* across disciplines

The sensations to transmit to people and *Cultural conditions* are absent in the Engineering case study; *Users satisfaction* and *Undeveloped knowledge*, are absent in the Graphic design case study due to the use of different terminology – Graphic designers do not refer to the user, but the reader; *New policies limitations*, are absent in three case studies with exception to Architecture – recent new policies regarding energy certification demand the creation of systematic knowledge and solutions for a responsive design process.

On the other hand, a dominant sub-category shows standard deviation in the Interaction design case study, thus *The sensation to transmit to people* is a clear variant driver of *Priority Value* across the four design disciplines and particular to Interaction design.

Non-dominant sub-categories seem to be important, for example: *New policies limitations*, *Cultural conditions* and *Users satisfaction*, are equally important in the Architecture case study; *Undeveloped knowledge* and *Users satisfaction* are still important drivers of *Priority Values* to the Mechanical engineering case study; *The sensation to transmit to people* and *Cultural conditions* are still important drivers of *Priority Values* to the Graphic design case study; *Users satisfaction*, *Undeveloped knowledge* and *Cultural conditions* are still important drivers of *Priority Values* to the Interaction design case study. Such variance is shown in Table 5.11.

Table 5.11. Variant *Priority Value(s)* across disciplines

Sub-categories	**Graphic design**	**Architecture**	**Interaction design**	**Mechanical engineering**
The sensations to transmit to people	▨	▨	▨	
Users satisfaction		▨	▨	▨
Undeveloped knowledge		▨	▨	▨
New policies limitations		▨		
Cultural conditions	▨	▨	▨	

Sub-categories of invariant drivers of *Priority Value* with incidence above 5 % in one or more design disciplines are shown in Figure 5.9. Two drivers of *Priority Values* are dominant in the Mechanical engineering case study, namely, *Technology conditions* and *Foreseeing the experience through simulation.*

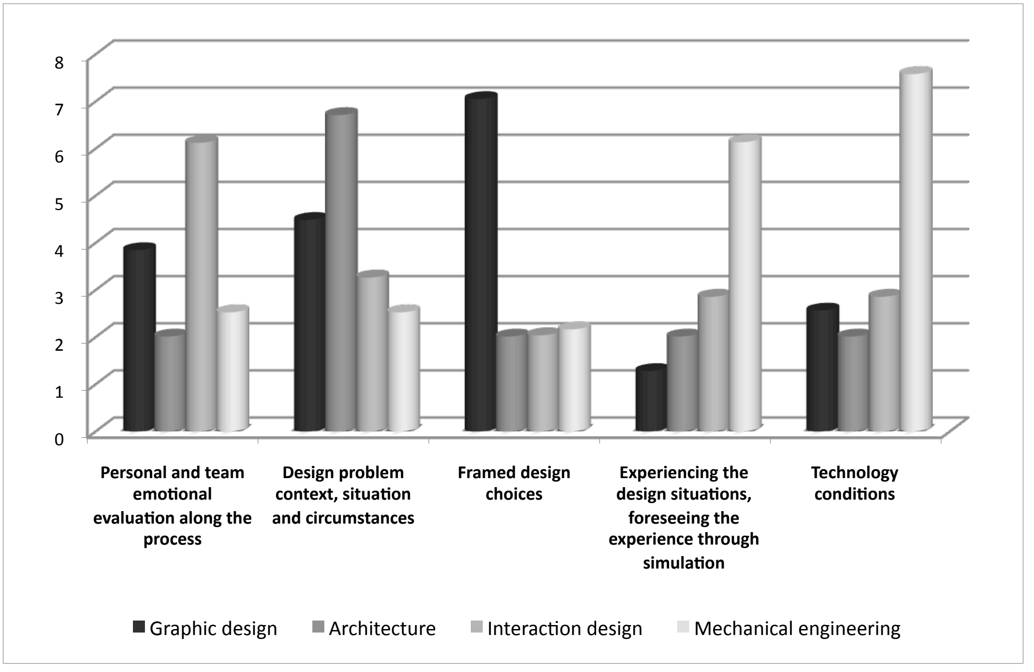


Figure 5.9. Dominance of invariant *Priority Values* across disciplines

Each one of the other three design disciplines show one dominant driver of *Priority Value*, namely: *Framed design choices* in the Graphic design case study; *Design problem context, situation and circumstances* in the Architecture case study; *Personal and* team *Emotional evaluation* in the Interaction design case study.

In spite of the diversity of designers *Value* systems, commonalities and differences can be inferred from designers' reports of drivers of action related to *Value* management. The managerial implications and guidelines derived from the analysis of the results so far were:

- The study depicts categories that may help to establish a support to a better understanding of language between design disciplines at the moment the design actors know they share *drivers of Priority Value.*

Summary

The following variant and invariant categories are drivers of *Priority Value* in design across the four case studies:

- Invariant categories of drivers of *Priority Value*, Five main categories of 28 sub-categories show significant frequency across the cases.
- Variants of drivers of *Priority Value*, Five sub-categories vary across the four case studies, from a specific to a dominant rate.

Drivers of *Priority Value* are intertwined with *Flow conditions* and *Flow breaks*, as they can hinder or foster designers' actions and made them remain in *Flow* according to its influence and consequences in the design process.

This study, brings into evidence that *Flow* in design is inherent to mental and physical actions to assure break or stop continuity with influence in management, goal, process direction and strategic tasks. The translation of *Flow* in design allows the identification of sources of *MUDA* and its positive effects.

This categorization system was presented to the panel of evaluation for feedback on a Likert scale based questionnaire (see Appendix B). Results show an agreement of 79,4% with the categorization system. Average of codes across categories is 4 (1-5). The average of four categories is over 4 and one is 3,7, namely intuitive-based priority. The average of importance attributed to the 5 categories is 5 (1-6), three categories over 5 and two of 4,7 and 4,8. The inter-rater reliability test shows an agreement of 50% of first and second level categories. Disagreement relates to overlapping between the categories of rational and constraints-based drivers for decision-making, but essentially because the external researcher did not recognize three of the four sets of two drivers. Table 5.12 sums the results regarding the research sub-questions so far.

Table 5.12. Overview of research sub-questions and results so far

<table>
<tr><th>Lean Principle</th><th>Dimensions of analysis</th><th>Research sub-questions</th><th>Results</th></tr>
<tr><td rowspan="4">Value</td><td>Identify Value from designers perspective</td><td colspan="2">What do designers' Value in design across disciplines?</td></tr>
<tr><td colspan="2">Studies I and II Based on interviews</td><td>Categories of Value for designers</td></tr>
<tr><td>Identify how designers deliver Value in action</td><td colspan="2">How do designers deliver value to the design process and design results in design meetings?</td></tr>
<tr><td></td><td colspan="2">Described in 5.1.4 Investigating Pull in design</td></tr>
<tr><td rowspan="4">Value Stream</td><td>Identify characteristics of designers' approach</td><td colspan="2">Do designers sharing the same design environment show the same design approach characteristics?</td></tr>
<tr><td colspan="2">Study IV Based on interviews</td><td>Categories of characteristics of designers' approach</td></tr>
<tr><td>Mapping MUDA in design</td><td colspan="2">How to map MUDA in design across different design disciplines?</td></tr>
<tr><td></td><td colspan="2">Described in 5.1.5 Investigating MUDA in design</td></tr>
<tr><td rowspan="4">Flow</td><td>Identify Flow circumstances</td><td colspan="2">What are designers' Flow stops, breaks and conditions?</td></tr>
<tr><td colspan="2">Study IV Based on interviews</td><td>Flow breaks and Conditions</td></tr>
<tr><td>Identify Flow interaction sequences</td><td colspan="2">How do designers deliver value to the design process and design results in design meetings?</td></tr>
<tr><td></td><td colspan="2">Described in 5.1.4 Investigating Pull in design</td></tr>
<tr><td rowspan="4">Flow and Pull</td><td>Identify what do designers Value in decision-making</td><td colspan="2">Which invariant characteristics across different design disciplines can be found in decision-making?</td></tr>
<tr><td colspan="2">Study V Based on interviews</td><td>Categories of priority Value in decision-making</td></tr>
<tr><td>Interdependency and Iteration in design</td><td colspan="2">How do instances of value judgment evolve in design meetings across design disciplines?</td></tr>
<tr><td></td><td colspan="2">Described in 5.1.4 Investigating Pull in design</td></tr>
</table>

5.1.4 Investigating *Pull* in Design

This chapter describes Studies VI and VII for the translation of the Lean Principle of *Pull* in design meetings and complementary results from Study III.

Priority Issues in instances of *Value* judgment

The analysis and mapping of meetings show that *Priority Issues* are discussed in instances of *Value* judgment (Figure 5.10) that can take three different stages:

- Passive, when someone calls for the discussion of an issue without receiving attention, reemerging later in the process.
- Iterative, when an issue is discussed still without final conclusion.
- Definitive, when a decision is assigned to an issue. Definitive instances can become iterative if the decision is not final.

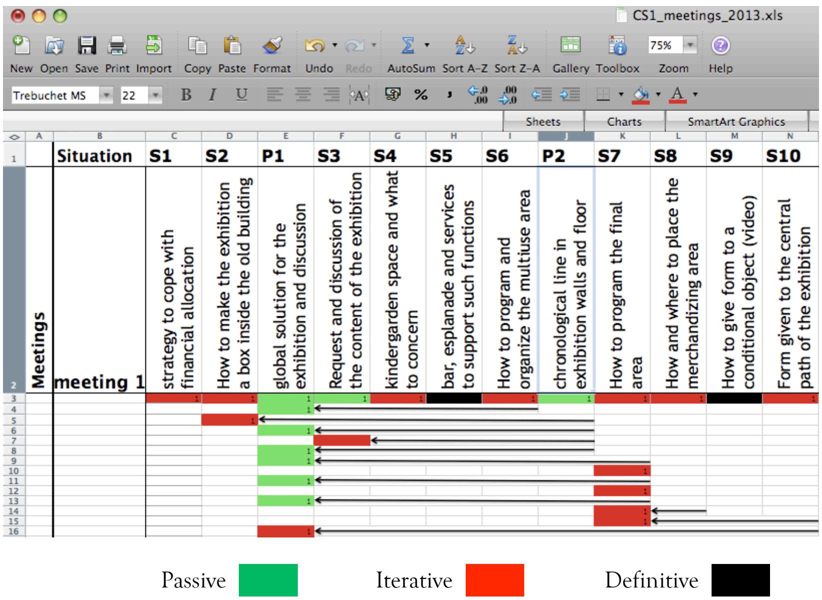


Figure 5.10. Mapping of instances of *Value* judgment in meetings

The definitive instances have immediate decision. The iterative instances are dependent on different but related instances of *Value* judgment. The instances of *Value* judgment occurred during the meetings under the following circumstances: each time a *Priority Issues* is brought into discussion an instance of *Value* judgment is settle to which an output is given – an immediate or postpone decision. Instances of *Value* judgment evolved towards finding the matching solution to each *Priority Issue*. Members of the team brought *Priority Issues* into discussion. The leading designer or the client's main representatives gave the output to each instance of *Value* judgment and *Priority Value(s)* support the discussion and settled designers' lines of argumentation.

The following examples are based on transcripts of an iterative and a definitive instance of *Value* judgment from a design meeting. In this transcript a discussion evolves around the issue without final decision. Partial choices and measures are taken to reach a solution, thus it remains an iterative instance of *Value* judgment. The *Priority Issue* is: *How to integrate the kindergarten space.*

> *'Designer A – We will do here the space for the children (Pointing out in the drawing of the plan).*
>
> *Client B – Even for another reason.*
>
> *Designer A – If it was there, the parents would have to walk 400 meters (Pointing out in the drawing of the plan).*
>
> *Client B – There is other unbeatable argument. We would need 70 000 Euros to have that space in good conditions. It's out of question.*
>
> *Designer A – Hei! no. It's better to spend it here (Pointing out in the drawing of the plan).*
>
> *Client B – we can do it in one of two places. It happens here, or it happens there as a multiuse space with programmed activities for the children, and programmed activities for adults in the evenings. We can use the same materials. I will speak again with X explaining the alternatives so that she can reformulate her proposals.*
>
> *Designer A – My idea is the following. In one of our Wednesday's meetings we would meet your specialists just to tackle this part. Or you give us an A4 with what could be the program of activities for the children. Because, we don't have to use all*

this area, we can just use this one, which is huge. See the scale. So, in the floor, we use the typical material you use in public children playgrounds, and a slide, those balls where they jump in, those things with ropes that they climb, tables and chairs so they can have atelier activities, and toilettes just for children, and, once there will be little ones, an area where they can take a nap. In this same area we need a compartment to have some food and drinks for the children. The program you will give to us will lead to the organization of this space. What we think is that this might be the right place. People get out of the exhibition and can walk through this way or that way, we'll see, and end up here to collect their coats. They left their coats here in the beginning thus, we would have a wall here, marking the entrance to the children's place. It's completely isolated (Pointing out in the drawing of the plan).

Client A – Can I give a suggestion? (Affirmative movements from the others) Take some of this area – from an exit point of view, some people might even arrive in groups – to have a lounge of arrival and departure.

Designer A – Very well. So we move the children area here and have the lounge there. This can be support area for both (Pointing out in the drawing of the plan).'

Set 4. 00:05:40:00 – 00:09:12:16.

In the following transcript the discussion evolves around the *Priority Issue*, *How to integrate a bar, esplanade and services to support such function*, with a final decision, thus the utterance is a definitive instance of *Value* judgment.

'Designer A – In the same way, we have to study with you the best place for the esplanade and supporting services for a canteen.

Client B – It's outside.

Designer A – At open air?

Client B – What was planned is to give support not just there but also outside, and to the foundation in general. (Pointing out in the drawing of the plan)

Designer A –Very well.

Client B – In the outside there is an area with a container, a lawn around it and a pine. It's a nice setting with shadow.

Client A – On that support we can have a deck, a kiosk and some tables and chairs.

Designer A – Then, we just have to provide the caviar.'
Set 5. 00:09:12:17 00:10:19:17

Study VI provided the following preliminary results on the analysis of meetings:

- Evidence of a shared model of interaction between designers and stakeholders in instances of *Value* judgment in meetings.
- Individual, team, the design-object and external needs, must or wishes as sources of *Priority Issues.*
- The major difference between designers and clients' perspectives is that designers have a holistic and more complete view of how to conceive and materialize the solutions while the clients have an assembled view and images of the process instead.
- A different level of design issues emerges from the analysis of the meetings that cannot be assessed in interviews. *Priority Issues* stated in interviews relate to designers' individual experiences and concerns while the *Priority Issues* discussed in meetings are mainly project-related.
- In design, The Lean Principle of *Pull* relates to priority, activation of the next actions setting the process path, iteration and interdependency of incomplete *Priority Issues.*

Categories of *Priority Issues* for decision-making

Study VII extended the objectives of Study VI to the first cross-case analysis of meetings of this research. The *Priority Issues* and its instances of *Value* judgment were mapped for each of the three groups of meetings from the case studies in Graphic design, Architecture and Mechanical engineering.

From the analysis of the meetings across the three design projects, issues prioritized for discussion are planned or emerge during the process. In each instance of *Value* judgment, designers initiate the discussion of a *Priority Issue* and settle lines of argumentation.

Beyond instances of *Value* judgment, situations of reviewing, checking lists, up-dates, jokes relating to critical situations, delays, clarifying doubts, isolated reference and comparison to other projects occurred during the meetings. Such characteristics are common to the three design cases and became part of the analysis procedure.

The three groups of meetings were mapped in Excel for the analysis and visualization of iterative and definitive *Priority Issues* (Figures 5.11, 5.12, 5.13). From the morphology of these images it is possible to infer structural relationships of iteration and interdependency between *Priority Issues* across the three case studies.

Iteration is measured by the frequency of iterative instances of *Value* judgment per and across *Priority Issue.*

Interdependency is measured by the frequency of definitive instances of *Value* judgment per *Priority Issue* that can also be a consequence of iterative *instances of Value* judgment of other issues.

The mappings of the meetings show that the most iterative issues have frequent red rectangles representing instances of *Value* judgment. A black rectangle represents a definitive instance of *Value* judgment, which in total are fewer than the iterative instances. Passive instances are represented in green.

Priority Issues under situations of *MUDA* are represented in violet; some are highly iterative others have immediate solution.

In the Graphic design case study (Figure 5.11), the occurrence of utterances of *Value* judgment for 61 *Priority Issues*, scores 256 iterations. Such characteristics made the mapping look extended in height.

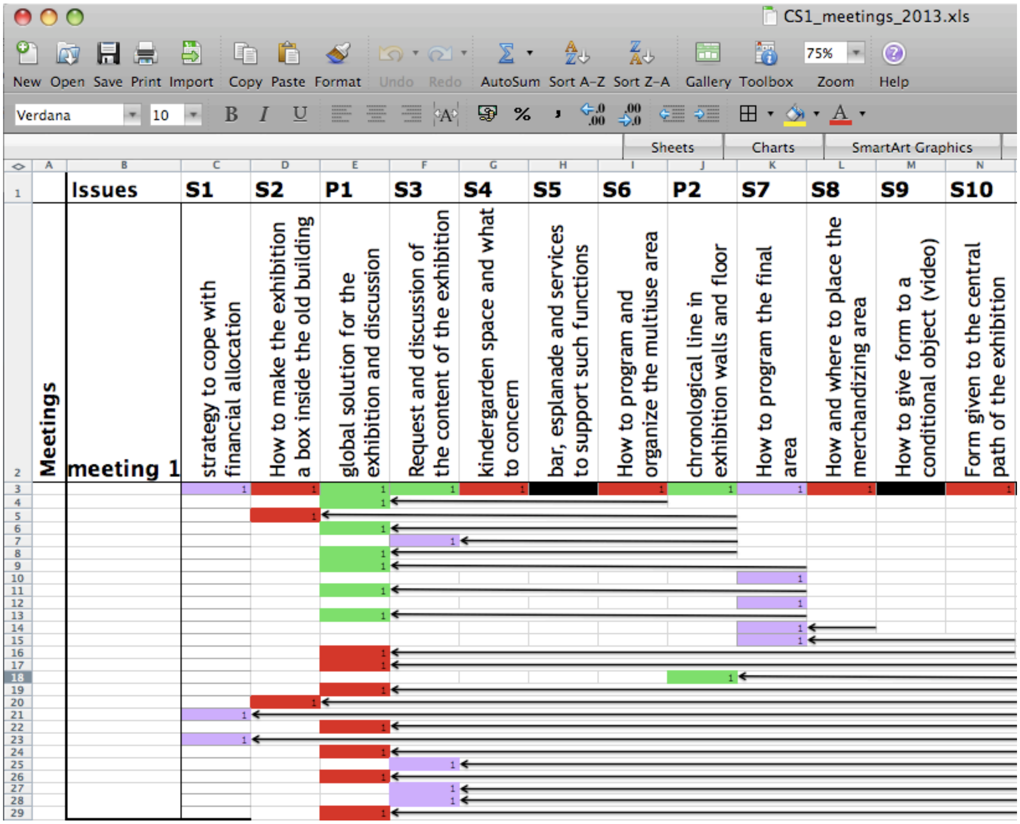


Figure 5.11. Mapping of the instances of *Value* judgment in the meetings of the design of the exhibition

A link of file is provided to the image above for an expanded illustration of the complete mapping (https://feupload.fe.up.pt/get/5O3GtHX7H52y2Xy).

In the Architecture case study (Figure 5.12) 92 *Priority Issues* were analyzed and show to be more interdependent, with 64 iterative *Priority Issues* and 56 interdependent *Priority Issues*. An incidence of 206 iterations of instances of *Value* judgments together with a high interdependency and more *Priority Issues* than the previous case made the mapping look extended in width.

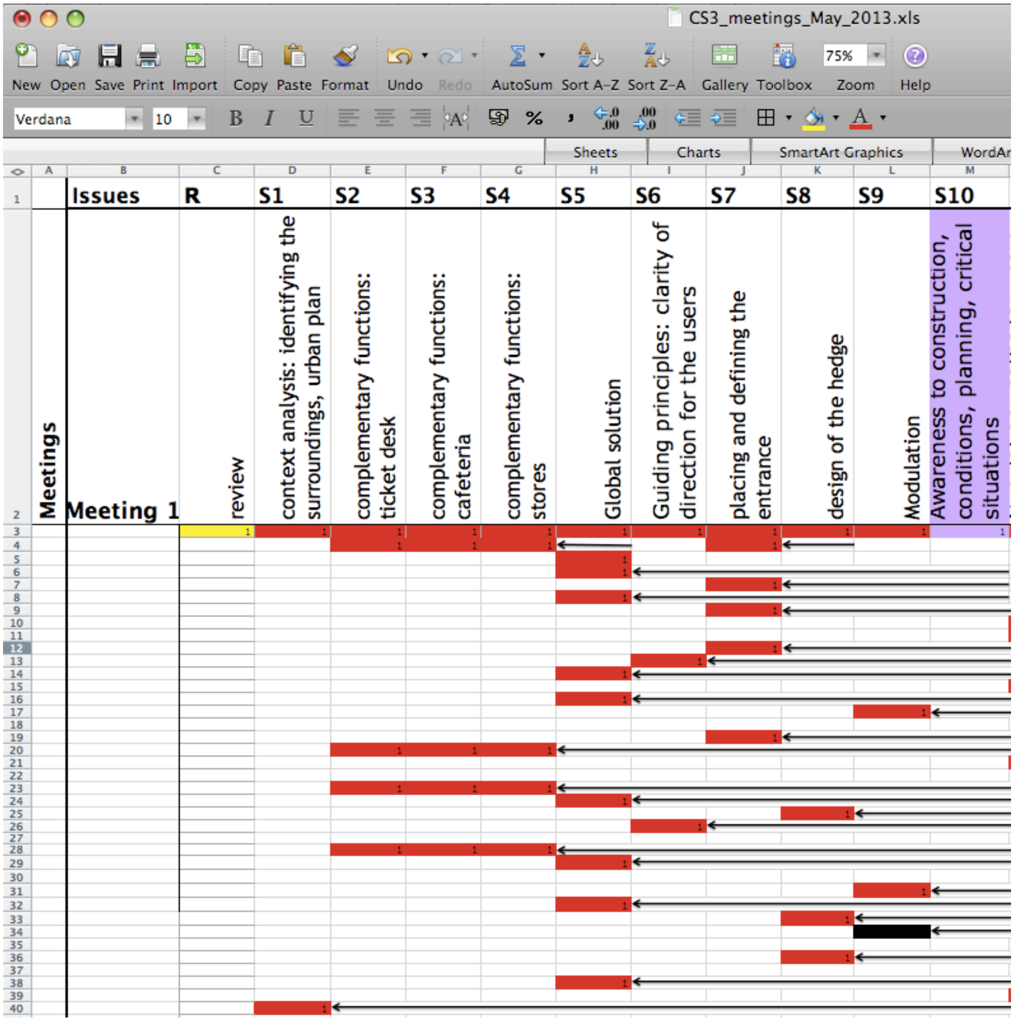


Figure 5.12. Mapping of the instances of *Value* judgment in the meetings of the train interface design

A link of file is provided to the image above for an expanded illustration of the complete mapping (https://feupload.fe.up.pt/get/QRUUo0qLleCLmfk).

In the Mechanical engineering case study (Figure 5.13), 122 iterative *Priority Issues* had a total of 105 iterative instances of *Value* judgments and 27 interdependent and definitive instances. Such characteristics made the mapping look short in height and the most extended in width.

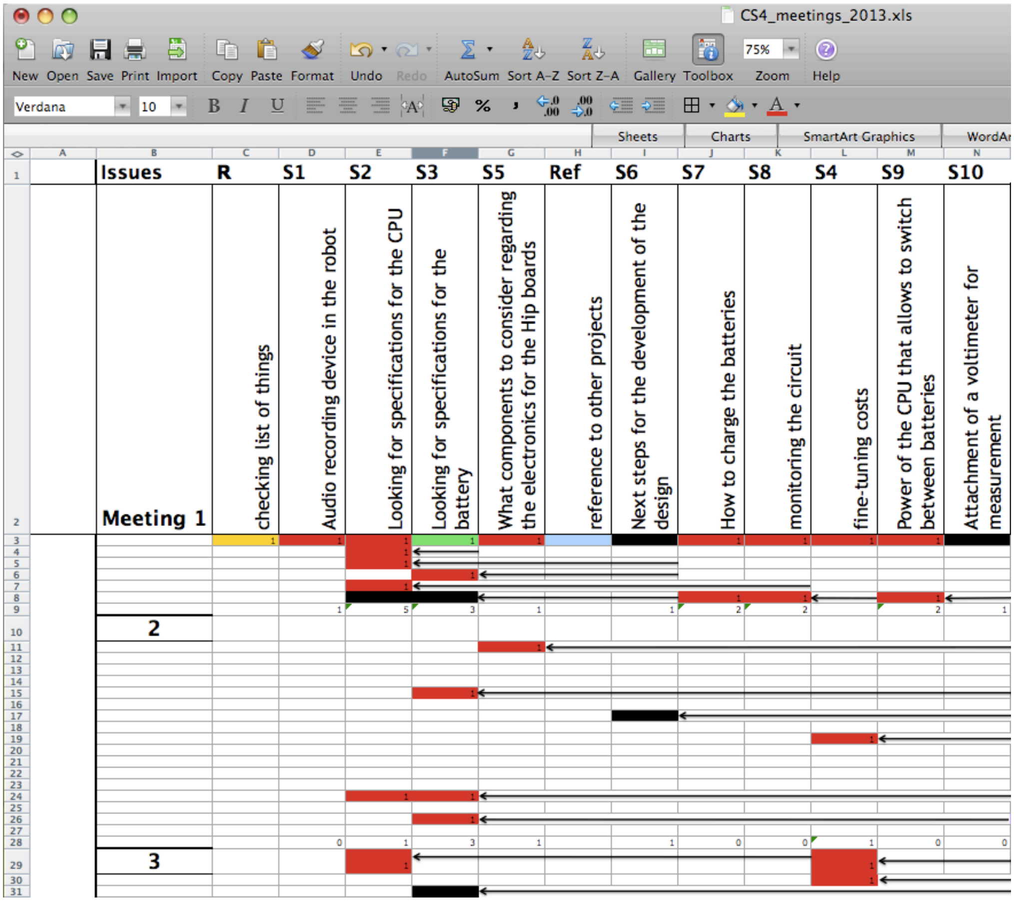


Figure 5.13. Mapping of the instances of *Value* judgment in the meetings of the train interface design

More issues were raised than in the other two projects, but less interdependent, thus with more independent decisions. A link of file is provided to the image above (https://feupload.fe.up.pt/get/w2Xs1h835dhS38K) for an expanded illustration of the complete mapping

In the design of the robot, designers had to deal with more *Priority Issues* regarding components, sub-components, systems, and specify characteristics. Interdependency relates to essential elements to make the robot operational such as requests for testing and outsourcing.

In the design of the train station interface, the highest amount of interdependency relates to small changes that have repercussion in the structure of the global design solution.

In the design of the exhibition, the highest iteration relates to the search for content and representations to each part of the exhibition with influence in the global design.

The above mentioned aspects are potential sources of *MUDA*, as waste, *Value* loss or necessary *MUDA*, with its positive or negative effects, and hopefully for a better *Value* definition. The study takes a closer look at the following frequencies per and across case studies:

- *Priority Issues*
- Iterative *Priority Issues*
- Iteration of Instances of *Value* judgment
- Interdependent *Priority Issues*
- Interdependency in instances of *Value* judgment

Iteration in meetings across Case Studies

The Iteration of *Priority Issues* across the case studies is shown (Table 5.13). The Graphic design case study, shows the higher frequency of iteration. One reason for the frequent iteration is due to the delays in receiving the content of the exhibition from the client. The Architecture case study shows less iteration and higher incidence of interdependency between *Priority Issues* than the Graphic design case study. In the Engineering case study, the number of *Priority Issues* is even higher and iterative issues are fewer. A detailed analysis of *Priority Issues* iteration across cases is further developed.

Table 5.13. Total and relative numbers of *Priority Issues* and iteration per Case Study

Case Study	**Project**	**Priority Issues**	Relative Numbers (%)	**Iterative Issues**	Relative Numbers (%)	**Iterative Instances**	Relative Numbers (%)
Graphic design	Exhibit	61	22,2	41	25,8	256	46,1
Architecture	Train interface	92	34,4	62	40	206	37,1
Mechanical engineering	Robot	122	44,4	56	35,2	105	16,8

In the Graphic design case, the most iterative *Priority Issues* are design related, namely: *explanation and discussion of the global solution*, *request and discussion of the content of the exhibition*, *providing awareness for the construction of the exhibition*, *form given to the central path of the exhibition* and *form given to the last path of the exhibition.*

In the Architecture design case study, the most iterative *Priority Issues* are design related, namely: *explanation and discussion of the global solution*, *modulation*, *supporting structure*, *people circulation path and space organization*. In both cases the iterative *Priority Issues* relate to the *global design solution*, *structural support* and *construction*.

In the Mechanical engineering case study, the most iterative *Priority Issues*, are design and non-design related, namely: *discussion about production planning and deadlines*, *looking for specifications for the CPU*, *looking for the specifications for the battery*, *design of the hip board*, and *fine-tuning costs.*

Interdependency in meetings across Case Studies

The interdependency of *Priority Issues* and instances of *Value* judgment in meetings across the case studies is described (Table 5.14). The Architecture case study shows high interdependency of *Priority Issues* with 56 interdependent instances of *Value* judgment. Every single change, or replacement of an element would change the modulation and consequently the supporting structure and global design. One decision involved many other *Priority Issues*. In the Graphic design case study, the interdependency of *Priority Issues* relates to missing information of the content of the exhibition. In the Engineering case study interdependency relates to the requirements for testing and outsourcing.

Table 5.14. Total and relative numbers of interdependency per Case Study

Case Study	Project	Interdependent Priority Issues	Relative Numbers (%)	Interdependent Instances		
				Total	Min issues	Max issues
Graphic design	Exhibit	11	21,6	13	2	4
Architecture	Train interface	25	49,0	56	2	8
Mechanical engineering	Robot	15	29,4	27	2	4

Invariants

Five main categories of *Priority Issues* derived from a qualitative and quantitative understanding are described (Table 5.15). Examples of *Priority Issues* are given to the sub-categories. Categories of *Priority Issues* relate to the activities of recognizing and defining the *Situation*, *Strategy*, *Measuring*, *Validation* and *Collaboration* in the design approach to the design problem and solutions during the design process. Such categories name clusters of *Priority Issues* that have a comparable role with the Lean Principle of *Pull*, pulling the trajectory of finding solutions and making decisions for the final result. A definition provided to each category is further described.

Table 5.15. Invariant categories of *Priority Issues* across the three Case Studies

Invariant Categories of *Priority Issues*		
Categories	**Sub-categories**	**Examples of *Priority Issues***
Situation	**Contextual characteristics**	Identifying the main elements in the surroundings
	Complementary functions	Locating and design of the waiting area
	Conditional elements	Where to place technical areas
	Access	Access to remove equipment
Strategy	**Global design**	Explanation and discussion of the global solution
	Guiding principles	Clarity of direction for the users
	Anticipation strategies	Next steps for the development of the design
	Prevailing strategies	Strategy to cope with norms and constraints
Measuring	**Space**	Space organization
	Structure	Supporting structure
	Form	Fine-tuning proportion
	Detail	Constructive detail of coating
	Costs	Fine-tuning costs
Validation	**Safety**	How to guarantee safe circuit
	Building	Request to simulate the parts assembled
	Testing	Request for testing
Collaboration	**Information**	Exchange of information with stakeholders
	Outsourcing	Added value of outsourcing services
	Technical drawings	Request for technical drawings

Situation - The category *Situation* entails *Priority Issues* that emerge for the discussion of aspects of the design problem and *solution situational and contextual characteristics* and the design problem and solution specific circumstances for *functional objectives* and *conditional characteristics.*

Strategy - The category *Strategy* entails *Priority Issues* that emerge for the discussion of strategic aspects of the design problem and solution, defining streams of strategy for example, *conceptual design, guiding principles, prevailing aspects,* and *anticipation.*

Measuring - The category *Measuring* entails *Priority Issues* that emerge for the discussion of enumerable aspects of the design problem and solution that ask for actions of measuring, and therefore defining, for example, *space, structure, form, detail* and *costs.*

Validation - The category *Validation* entails *Priority Issues* that emerge from the discussion as needs that ask for validation of *mechanisms, structures* and *compliance with regulations* of the design problem and solution.

Collaboration - The category *Collaboration* entails *Priority Issues* that emerge from the need to discuss, share or create interdependencies, to solve aspects of the design problem and solution.

Once again, coding, clustering and organizing a categorization system of *Priority Issues* improved the identification of potential sources of *MUDA,* as waste, *Value* loss or necessary *MUDA*, with its negative or positive effects, for a better *Value* definition.

Variants

The most iterative *Priority Issues* relate to the category of *Strategy,* namely, to reach a *global design*, to assure *prevailing characteristics* and *anticipation* management. Incidence of sub-categories of *Priority Issues* per project set of meetings show a particular governing role of such issues in the development of the designs. For example, the sub-category of *Form* seems to have a particular role in *pulling* the design of the exhibition. The sub-categories of *Guiding principles, Structure* and *Space,* also have a dominant role in *pulling* the trajectory of the design of the train interface and the sub-categories of *Detail* and *Costs* also *Pull* the trajectory of the design of the robot. The most iterative *Priority Issues* are dominant in the categories of *Strategy but also Measuring* as illustrated in Table 5.16.

Table 5.16. Categorization and frequency of the most iterative *Priority Issues* per case study

Case Study	Priority Issues		Most Iterative Priority Issues	Freq.
Exhibition	**Strategy**	**Global design**	Explanation and discussion of the global solution	30
		Prevailing	Request and discussion of the exhibition content	33
		Anticipation	Providing awareness for the construction, constraints, planning and critical situations	20
	Measuring	**Form**	Central path of the exhibition	11
			Last path of the exhibition	10
Train interface	**Strategy**	**Global design**	Explanation and discussion of the global solution	23
		Anticipation	People circulation: paths, stops, fluxes, control	17
		Guiding principle	Modulation	22
	Measuring	**Structure**	Supporting structure	20
		Space	Space organization	14
Robot	**Strategy**	**Anticipation**	Discussing the schedule for production planning and deadlines	23
	Measuring	**Detail**	Looking for specifications for the battery	9
			IMU, placement and connections	8
			Power board design	8
		Cost	Fine-tuning costs	10

The most interdependent *Priority Issues* are illustrated and categorized in Table 5.17. The design of the train interface shows the higher incidence of interdependency in issues that relate to: *strategy*; *guiding principles*; *measuring*; *structure*; *form*; *detail*; and *complementary functions* of the design problem situation and solution.

The sub-category of *Form* seems to have a more incident role determining interdependency of *Priority Issues* in the design of the exhibition. The sub-category of *Detail* seems to have a more incident role determining interdependency of *Priority Issues* in the design of the robot.

Table 5.17. Categorization and frequency of the most interdependent *Priority Issues* per Case Study

Case Study	Priority issues		Most Interdependent Priority issues	Freq.
Exhibition	Strategy	Global design	Explanation and discussion of the global solution	7
	Measuring	Form	Discussion of the 1st path of the exhibition	6
			Discussion of the 2nd path of the exhibition	8
			Discussion of the 3rd path of the exhibition	6
Train Interface	Strategy	Guiding principle	Modulation	9
	Measuring	Structure	Supporting structure	9
		Detail	Detail design: coating, transparency, frames, ceramics, ceilings, materials	7
		Form	Design of the façade	6
	Situation	Complementary functions	Locating and defining stores	5
Robot	Measuring	Detail	Detailing of the hip board	4
			Looking for specifications for the battery	4
			Looking for specifications for the CPU	3
	Validation	Testing	Request for testing	4
	Collaboration	Information	New stakeholders	5

The most interdependent *Priority Issues* are dominant in the categories of *Strategy* and *Measuring*, although the category of *Situation* seems to play an important role in the design of the train interface, and the category of *Validation* seems to play an important role in the design of the robot.

The dominant categories of *Priority Issues* with higher iteration and interdependency are illustrated in Table 5.18. This is true for the case studies under analysis. However, results cannot be generalized once other design projects that demand more innovation and concern for example, to the design problem situation can also take place in Mechanical engineering and Graphic design.

Table 5.18. Dominant iterative and interdependent priority issues across the three Case Studies

Priority issues	**Iteration**			**Interdependency**		
Categories	Exhibit	Train interface	Robot	Exhibit	Train interface	Robot
Situation					▨	
Strategy	▨	▨	▨	▨	▨	
Measuring	▨	▨	▨	▨	▨	▨
Validation						▨
Collaboration						▨

Model of interaction in *Value* judgment

Studies VI and VII provided the identification of an inductive *Flow* diagram of how designers' interact in design meetings across the three case studies (Figure 5.14). Three elements constitute the course of actions, namely:

- There is an input to discuss a *Priority Issue,* based on a 'need', 'wish' or 'must' in the terminology of design methodology (Pahl et al., 2007).
- There is an instance of *Value* judgment that can follows alternative courses of action. From the analysis of the request it can evolve in four alternative directions, namely: an immediate decision derived from a direct analysis; an evaluation stage where *Priority Values* emerge and guide a narrative discourse; the direct search for information or delegating activities and consequent feedback; and finally, an action-driven experimentation (a driver for *Flow*) stage that reinforces the narrative discourse of the design team. All the possible combinations between the paths are considered.
- There is an output situation where a team-based decision is made. Two things can happen, a decision based on the agreement of a solution, or a postponed decision based on alternatives of solution. The former situation leads to iterative instances of *Value* judgment through the meetings until reaching a final decision.

The same *Flow* diagram is extended to the behavior of stakeholders when delivering *Value* in design meetings yet with less influence in design decisions.

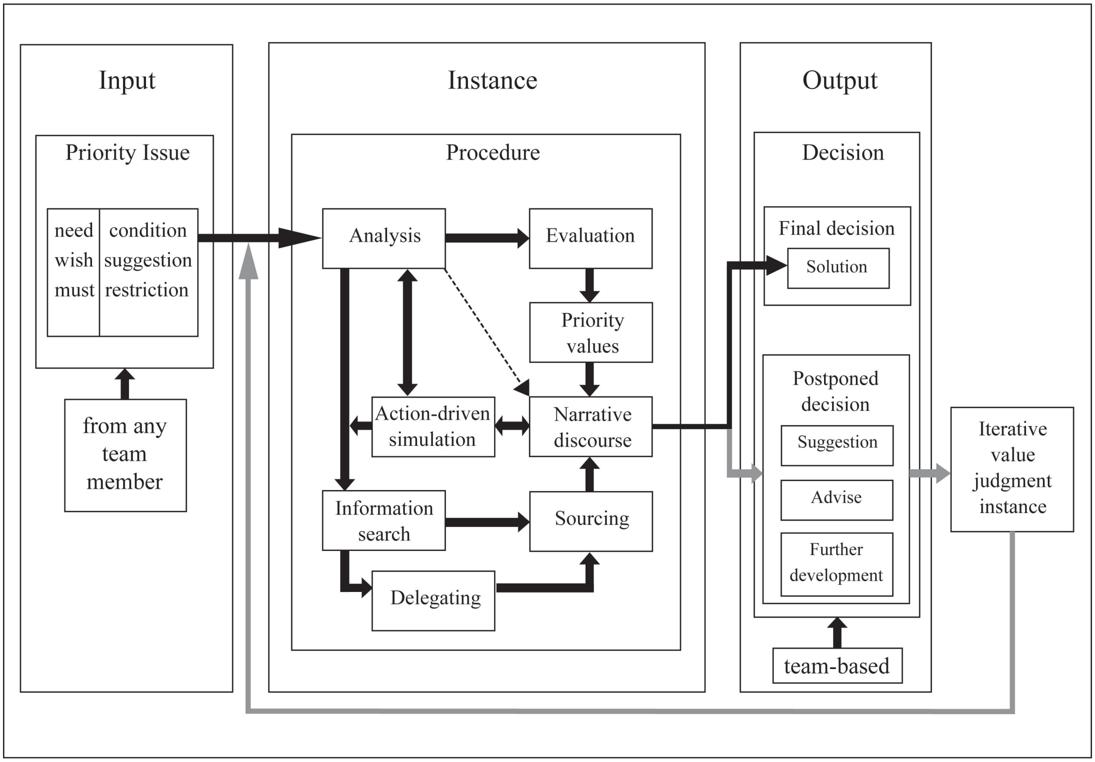


Figure 5.14. *Flow* diagram of interaction in *Value* judgment in design meetings

The identification of the four alternative directions of the course of actions derived from different characteristics of interaction identified in each case study. For example, immediate decisions that derive from a direct analysis is a common path across the three case studies; the evaluation stage where *Priority Value(s)* emerge and guide a narrative discourse was more frequent in the Graphic design and Architecture projects; the direct search for information or delegating activities and consequent feedback was frequent in Mechanical engineering; and finally, an action-driven experimentation stage that reinforces the narrative discourse of the design team was present in all the cases with special incidence in Architecture due to the importance given to sketching. In study VI, the narrative discourses between elements of the design team and client's team were based on the minimization of input measured as cost, and the maximization of output in terms of result.

The investigation of *Pull* in design includes Study III, further described. This study was considered helpful to the identification of *MUDA* and coping mechanisms in design, and underpinned the importance of developing a framework of awareness to Lean Principles and *MUDA* in design. Results made the study suitable to the investigation of *Pull* in design.

Elements of Mechanisms to cope with situations of crisis

The identification of aspects on the influence of the current times of economic crisis clearly became pertinent in the data gathered from interviews. Motivation for Study III stemmed from designers and managers interviews describing mechanisms to cope with crisis situations comparable to the Lean principle of *Pull*.

> *"The language, and the processes which stem from it, merely release the fundamental order which is native to us. They do not teach us, they only remind us of what we know already, and of what we shall discover time and time again, when we give up our ideas and opinions, and do exactly what emerges from ourselves."*
>
> Christopher Alexander, 1979. *The timeless way of building,* p. 660

Results describe elements of mechanisms to cope with the influence of times of crisis, differing perspectives and concerns. This study showed that *MUDA* as *Value* loss is current in the daily life of design offices in times of crisis. These mechanisms encompass four main elements namely, *Influence, Individual heurism, Process* and *Goal* as situations that ask for reactions summarized in Table 5.19 across managers with design and non-design background. Findings show that in time of economic crisis managers and designers are more aware and motivated to consider taking prudent risks, identifying new opportunities and creating space for change and innovation, with a long-term view to provide their companies with a higher competitive advantage and greater financial sustainability. They activate mechanisms that remain hidden in times of normal circumstances. The study illustrates examples that influence performance and prepare design organizations to deal with crises, and a consequent damage reduction in recovering stage.

Table 5.19. Elements of mechanisms to cope with crisis situations considered by managers and designers

Main Categories	**Situations**	Managers non-designers	Managers designers
Influence	Internal pressure		▨
	Time pressure	▨	▨
	Economic pressure	▨	▨
Individual Heurism	Make the difference	▨	▨
	Creating opportunities		▨
	Keep critical sense		▨
Process Flexibility	Procedural flexibility		▨
	Planning flexibility	▨	▨
	Strategic flexibility	▨	
Goal	Financial sustainability	▨	▨

Study III identifies situations and behavioral examples that activate mechanisms to cope with the influence of times of crisis situations. Besides asserting coping mechanisms, managers and designers' statements also refer aspects and actions to keep a culture of awareness and prevention in the working environment that can prepare people to cope with these circumstances. These aspects regard three main categories namely, *Motivation*, *Anticipation* and *Structure*, as shown in Table 5.20. Each category relates to actions as characteristics of the companies' culture to avoid unawareness, damage to routine mechanisms and activate early signal detection mechanisms to non-routine situations. Crisis awareness leads to replacing routine. These aspects encompass a feeling of uncertainty usual to the designing context to which designers are skilled dealing with.

Table 5.20. Managers and designers' aspects of awareness and behavioral examples to cope with crisis

	Behavioral examples to cope with crisis situations			
Aspects	Strategic-level	Tactical-level	Operational-level	Individual-level
Motivation	Create dynamic view	Avoid routine	Reward initiative	Ensure free opinion
Anticipation	Not taking anything for granted	Not presuming things are well formulated or organized	Not absorbing positive moments with too much enthusiasm	Be pragmatic
Structure	Planning	Organizing	Know people well	Recognizing limits

The context provided by the crisis might do not bring newness nor motivation for designers. On the other hand, this context activates designers' critical sense to review their role and the purpose of design as activity (Table 5.21).

Table 5.21. Influences and Consequences of Times of Economic Crisis in design consultancies

Main categories	**Economic Crisis Influence**	**Wicked Measures**	**Consequences**
Environment	Pressure to sell, Stress	New stricter rules, Over production	Quality crisis
Management	Looking for new markets Internal pressure	Not qualified decision	Decision crisis
Process	New policies, *Value* conflicts	Not enough reflection, Non-ethical behavior	Ethics crisis
Designer	Risk of incoherence, Dissatisfaction, no driving force	Repositioning, quit, deny, adapt	*Value* crisis
Performance	Fastness, Anxiety, Show off	Solution readjustment, mainstream solutions	Esthetic crisis

Designers strive to keep a route, contribute to change and well-being and for that, reviewing the purpose of the design activity and designer role remain essential features of designers' heuristics that can have prolific results in times of economic crisis.

Besides the general factors referred in the literature review, namely, corporate culture; values; communication; quality assurance; strategic planning; damage containment; other common factors to managers and designers are shown in Table 5.22. As a general influence of times of crisis, the managers reflect more on the opportunities, on the need to adopt more proactive and entrepreneurial attitudes without loosing the feeling of challenge that motivates the daily work. A change of mind is settled that leads to the adoption of opportune measures such as, rethinking existing strategies, augmenting professional networks, keeping and open-mind and willingness to do things not consider in periods of stability.

As advantages of dealing with times of crisis, the interviewees reported aspects such as, higher motivation to changing routines, having more time available to reflect on the processes and results, experiment new ideas, and devise new project proposals for design competitions. Economical crisis is seen as an opportunity to renew goals, looking further for more challenging situations and taking the best from each design opportunity.

This study showed that Lean Principles are comparable to the elements of mechanisms designers adopt coping with times of crisis, further referred. As consequences of reframing opportunities, routines and attitudes, space is created for the adoption of non-usual aspects leading to renew and change of design approaches *(Value Stream)*, with effects on results and a closely controlled approach to cost and budgets *(Value)*. Relevance is given to what managers' *Value* and sources of motivation as driving forces of behavior *(Flow)* such as aiming for financial sustainability, generating social change, evolution, and innovation *(Value and Pull)*.

Table 5.22. Behavioral examples in mechanisms to cope with situations of crisis

Main Categories	Situations	Behavioral examples
Influence	**Internal pressure**	Create space to think
	Time pressure	Keep motivation Be convergent
	Economic pressure	Rethink business orientation
Individual Heurism	**Make the difference**	New competences recognition Risk factor Always trying a difference
	Creating opportunities	Taking the best from each opportunity Seizing opportunities Interest recognition
	Keep critical sense	Rethink *Value* systems
Process	**Procedural flexibility**	Replacing routine Search for adequate solution
	Planning flexibility	Cope with a feeling of uncertainty New sources of motivation Initiative
	Strategic flexibility	Adapt business orientation
Goal	**Financial sustainability**	Long-term perspective Construction of trust and hip strategic zones Search for alternative financial resources Competitions proposals Accurate decision More management discipline

Times of crisis seem to be the proper context to rethink design. The managerial implications and guidelines derived from the analysis so far were: Identification of the influences, wicked measures and consequences of situations in times of economic crisis; Identification of the elements of mechanisms to cope with such situations and behavioral examples as crucial actions to activate these mechanisms; Development of a culture of awareness based on the aspects of motivation and actions on the strategic, tactical, operational and individual level of management activities; Rethink importance, priority and emergency as management criteria.

Summary

In design, the Lean Principle of *Pull* constitutes a set of elements, namely, *Priority Issues* that activate the next actions to take, lead to instances of *Value* judgment and iteration. Setting priority helps defining sequence, provides order, the process path and lines of argumentation to define *Value.* Results across the three case studies are:

- Invariant Categories of *Priority Issues.*
- Iteration and Interdependency characteristics of *Priority issues.*
- A *Flow* diagram of interaction in *Value* judgment in design meetings.

Study III strengthened the idea that identifying *Value* for designers', actions and mechanisms to cope with difficult situations were also dimensions of analysis for the translation of the Lean Principles into design. Results are considered elements of *Pull* mechanism. Table 5.23 sums the results for the research sub-questions so far.

The categorization systems of *Priority Issues* derived from studies VI, VII were not submitted to evaluation and feedback from a panel of research experts as it happened with the main categorization systems of this research. This is due to the fact that these studies were layers of analysis apparently deviant but essential to proceed with the identification of *MUDA* in design, and translation of the Lean principles in the design activity as explained. The inter-rater reliability test shows an agreement of 73% of first and second level categories. Disagreement relates to 11% of combined categories sub-categories for codes and overlapping between the categories of *strategy* and *situation..* For 16% of the combinations the researcher found alternate categorization for the categories of *strategy, validation* and *situation.*

Table 5.23. Overview of research questions and results *so far*

Lean Principle	Dimensions of analysis	Research questions	Results
Value	Identify *Value* from designers perspective	*What do designers' Value in design across disciplines?*	
	Studies I and II Based on interviews		Categories of *Value* for designers

	Identify how designers deliver *Value* in action	*How do designers deliver value to the design process and design results in design meetings?*	
	Study VII based on meetings Study V based on interviews		*Priority Issues* and instances of *Value* judgment Categories of *Priority Value* in decision-making
Value Stream	Identify characteristics of designers' approach	*Do designers sharing the same design environment show the same design approach characteristics?*	
	Study IV based on interviews		Categories of designers' approach
	Mapping *MUDA* in design	*How to map MUDA in design across different design disciplines?*	
	Study VII based on meetings		Mapping of instances of *Value* judgment and *Priority Issues*
Flow	Identify *Flow* circumstances	*What are designers' Flow stops, breaks and conditions?*	
	Study IV based on interviews		*Flow* breaks and conditions
	Identify *Flow* interaction sequences	*How do designers deliver value to the design process and design results in design meetings?*	
	Study VI based on meetings		*Flow* diagram of interaction in *Value* judgment
Flow and Pull	What do designers *Value* and prioritize in decision-making?	*Which invariant characteristics across different design disciplines can be found in decision-making?*	
	Study V based on interviews		Categories of *Priority Value* in decision-making
	Interdependency and Iteration in design	*How do instances of Value judgment evolve in design meetings across design disciplines?*	
	Study VII Based on meetings		Categories of *Priority Issues* Iteration and Interdependency of *Priority Issues* and instances of *Value* judgment
	Identify *MUDA* sources and coping mechanisms	*How do managers with design and non-design background working in the design environment cope with situations of the current crisis?*	
	Study III Based on interviews		Influences and consequences Elements of coping mechanisms Actions to activate coping mechanisms Development of a culture of awareness

5.1.5 Investigating *MUDA* in Design

The progression of studies to identify *MUDA* in design is briefly described and further explained. In a first step, the researcher identified situations in design that can be addressed to each type of *MUDA*. The translation was connected to results from studies I and II, and to the literature. Main concepts that relate to *MUDA* situations led to the recognition of behavioral characteristics that describe the actions of individuals in such situations. This translation stage was also based on the researcher experience.

The Lean Thinking nine types of *MUDA* (Ohno, 1988; Womack et al., 1996, 2003) were subject of a preliminary translation in the context of designing. In a first stage, the 25 selected interviews were analyzed according to the Lean Thinking nine types of *MUDA*. In an initial stage the LT types of *MUDA* provided a guiding framework in the analysis and clustering of *MUDA* in design.

The identification of the behavioral examples to each type resulted in preliminary notions for definitions and a framework to support collecting data along the empirical studies illustrated in Chapter 2 (Table 2.2). First results converged to three main dimensions of analysis, namely, *cognition*, *process* and *decision-making,* as streams of designers' behavior were *MUDA* could take place. Throughout the observation period the research was open to the recognition of other non-expected sources of *MUDA* situations and other behavioral examples.

This approach was helpful for a first screening of codes and clusters, and helped to identify other sources of *MUDA* but it also shed light on semantic overlapping as previously approached and further explained.

In addition, the analysis of *MUDA* types showed a prejudice, a negative connotation. For example, when looking for descriptions related to the *MUDA* of '*waiting*', interviewees did not always regard such situations as unhelpful. Many times, designers refer to situations of waiting as helpful, creating space to think or even a necessary pause to proceed. The different stages of the development of the final categorization system (Vieira et al., 2013) are further described.

Analysis of Types of *MUDA*: from Types to Categories

The studies I and II report results from the Graphic and Interaction design case studies, as previously mentioned. The identification of descriptions of behavioral examples related to each type helped in the translation of *MUDA* in design. Some types could not be perceived in the analysis of interviews transcripts. The *MUDA* of *Useless* and *Inventory*, although referred by some interviewees from the Interaction design case study, are mainly perceived through observation. Some *MUDA* recognized with more frequency indicated management issues. The types of *MUDA* with higher incidence are illustrated in Table 5.24.

Table 5.24. Types of *MUDA* with higher incidence in the Graphic and Interaction case studies

MUDA	**Behavioral examples**	
Types	**Graphic design**	**Interaction design**
Defects	-	Defects in execution
Over production	Work overload	Work overload and difficulty to think in the future
Movement	Difficulties in thinking due to interruptions	Difficulties in thinking due to interruptions
Waiting	Delayed information	-
Transport	Difficulties in communicating and gathering information from the clients	Difficulties of gathering information from the clients and to transport imagination
Complexity	Specific context circumstances	Difficulties in problem perception or client's complex structure of decision

The incidence of behavioral examples relate to situations such as *difficulty to transport imagination*, *difficulty to think under pressure*, *inappropriate focus of attention*, *difficulty to think in the future*, *difficulty to grasp the features of a problem derived from interruptions*, *the extension of timing for decision-making* and a *latent demand to create novelty*. The analysis of designers discourse lead to a preliminary overview of what types of *MUDA* can be detected in interviews as shown in Figure 5.15.

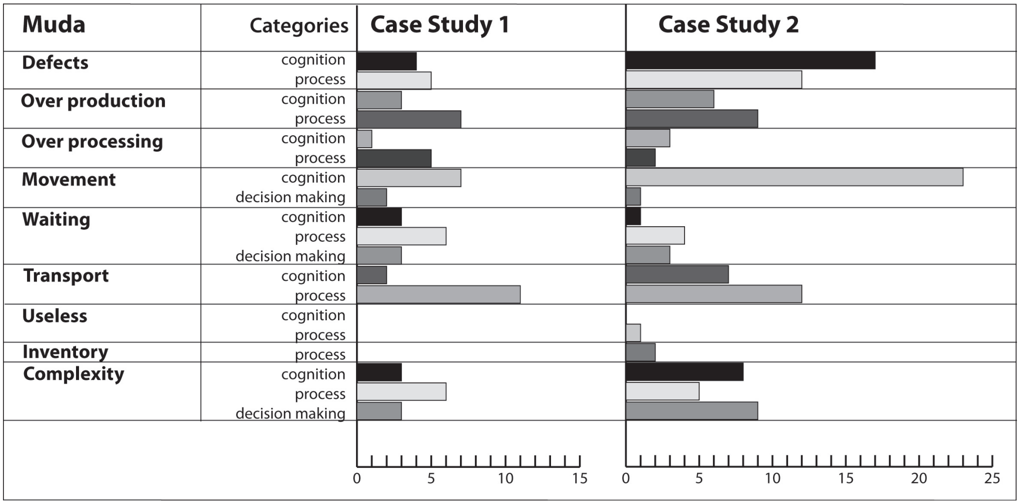


Figure 5.15. Identification of *MUDA* in the Graphic and Interaction design case studies (absolute numbers)

These behavioral examples converge to some degree of difficulty in performing actions. With these results, it became evident that *MUDA* happens as the cause or consequence of physical actions but also and to a great extent of mental actions. Thus, *cognition* and *decision-making* (Table 2.2) were initially proposed as streams of designers' behavior where *MUDA* can take place.

Compared to *Value* for designers, the incidence of *MUDA* described in the interviews shows a lower frequency (Figure 5.16). However, if the interviewees naturally described situations in this research regarded as *MUDA* it is due to its influence in the design process. Thus, *process* (Table 2.2) was initially proposed as the third stream of designers' behavior where *MUDA* can also take place. Such situations entail risks that designers might know or not, learned and recognized through experience and for which designers develop coping measures, adaptive behavior and strategies.

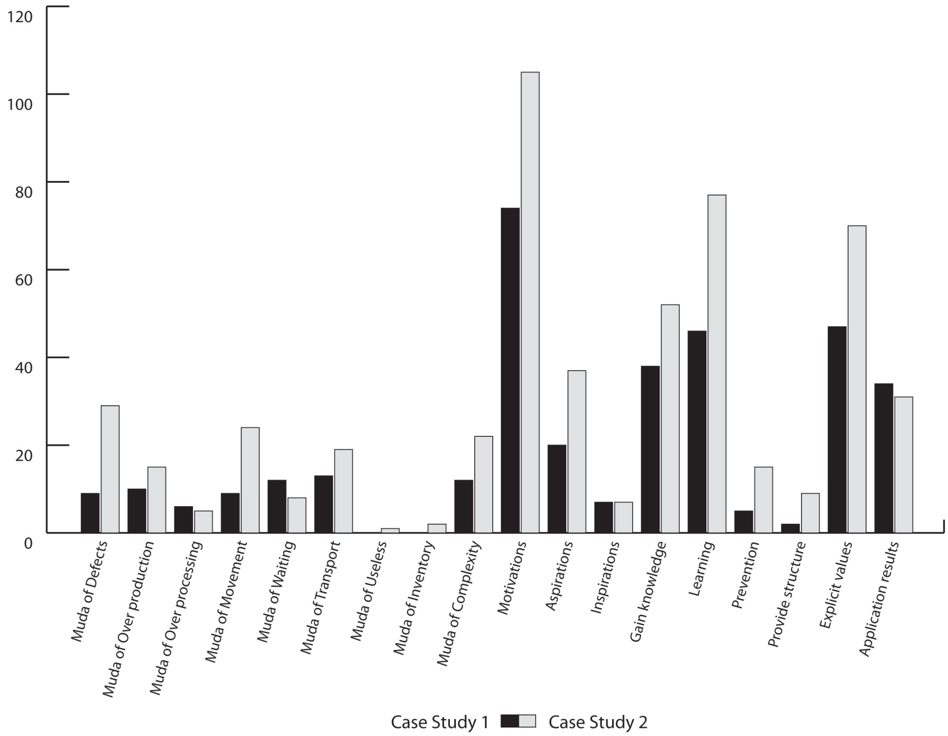


Figure 5.16. Overview of *Value* and *MUDA* in the Graphic and Interaction design Case Studies

A comparison of *Values* and *MUDA* identified in the interviews transcripts of three Graphic designers with different functions and tasks are illustrated in Figure 5.17. The most frequent *MUDA* detected by designer A are *Transport*, in the code, *difficulties in gathering information*, and *Movement*, in the code, *difficulties in thinking due to interruptions*. Thus, focused on *Quality* and *Economy* as explicit *Value(s),* designer A is more concerned with *Application results*, such as *Exchange,* of *information and feedback from the stakeholders and the leading designer*, and also on *Compensation* reflected in the assessment of *quality in design results.*

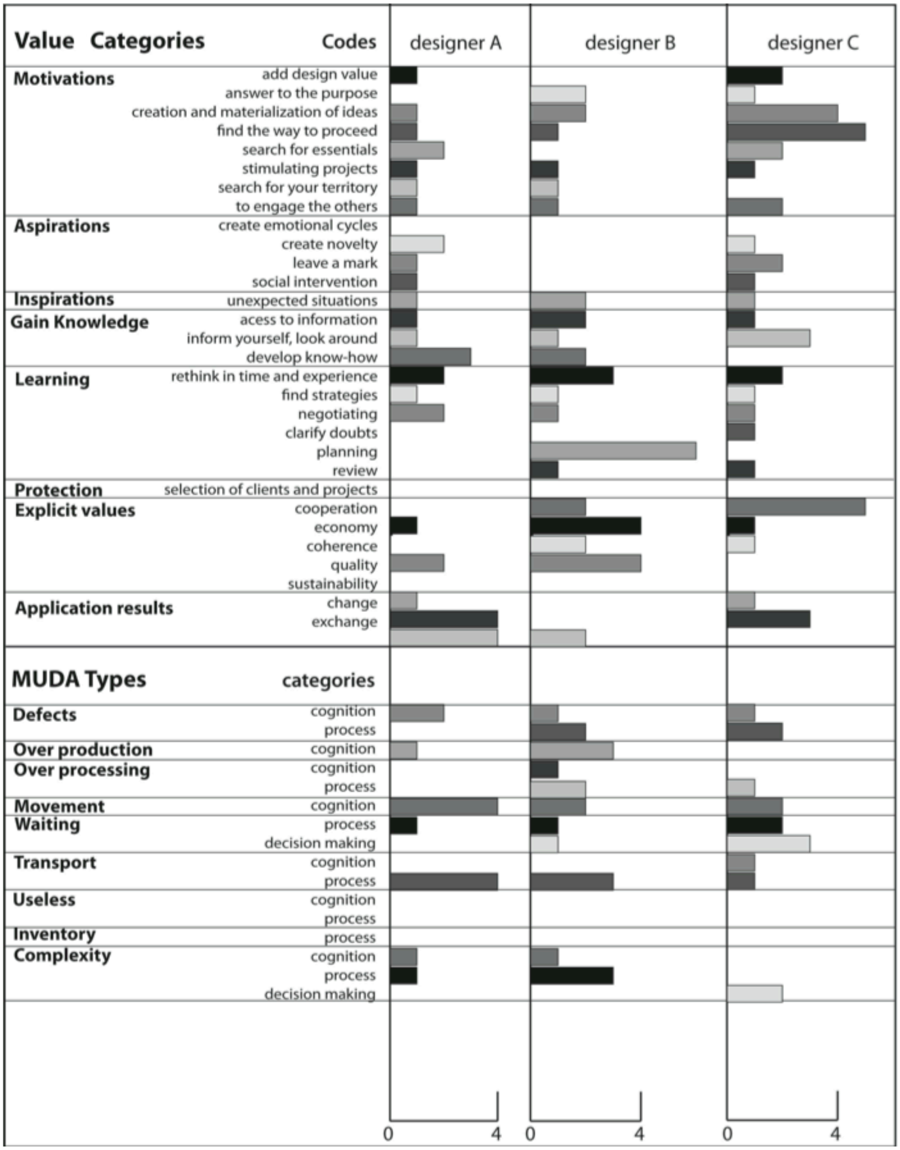


Figure 5.17. *Value* and *MUDA* in three interviews of Graphic designers with different tasks

Due to the nature of his activities the designer B detects more types of *MUDA* than the others. Designer B experiences particular ones such as *Defects,* in the execution of final results and *Over-processing,* in over-reliance due to clients and suppliers lack of planning. Thus, focusing on *Value(s)* as *Quality* and *Economy* designer B is concerned with *Learning* issues such as *Planning* and *Rethink in time and experience* to achieve *Cooperation* from stakeholders and the organizational team and *Coherence* in the final results.

Due to the nature of his activities the designer C detects a strong incidence of *MUDA* of *waiting,* in the process and decision-making while *finding the way to proceed* each time a new project starts, and the *MUDA* of *Complexity,* in decision-making dependent on *clients that are not sure of what they want*. Designer C is focused on a strong *Motivation* to create and materialize ideas, on the *Value* of *Cooperation* and actions of *Learning* and *Gaining knowledge*. These designers face different design management tasks and therefore common but also specific *MUDA* situations.

Some of the codes of the three main *Value* categories identified in 5.1, namely, *motivations, actions,* and *application results* were found in this analysis.

Studies I and II were extended to the identification of *MUDA* in four interviews from the Mechanical Engineering case study illustrated in Figure 5.18. Some *MUDA* recognized with more frequency indicated management issues. The engineer with management tasks described more *MUDA* situations. Allocations of types of *MUDA* differ according to the design tasks. The incidence of the *MUDA* types of *Transport* relates to interdependency in outsourcing, *movement* relates to difficulty to transport imagination, and difficulty to grasp the features of a problem due to its complexity.

The investigation of *MUDA* in design went through several stages. Nevertheless, results from these first studies based on the analysis of interviews from the Graphic and Interaction design and Mechanical engineering case studies brought important insights with influence in the orientation of the research.

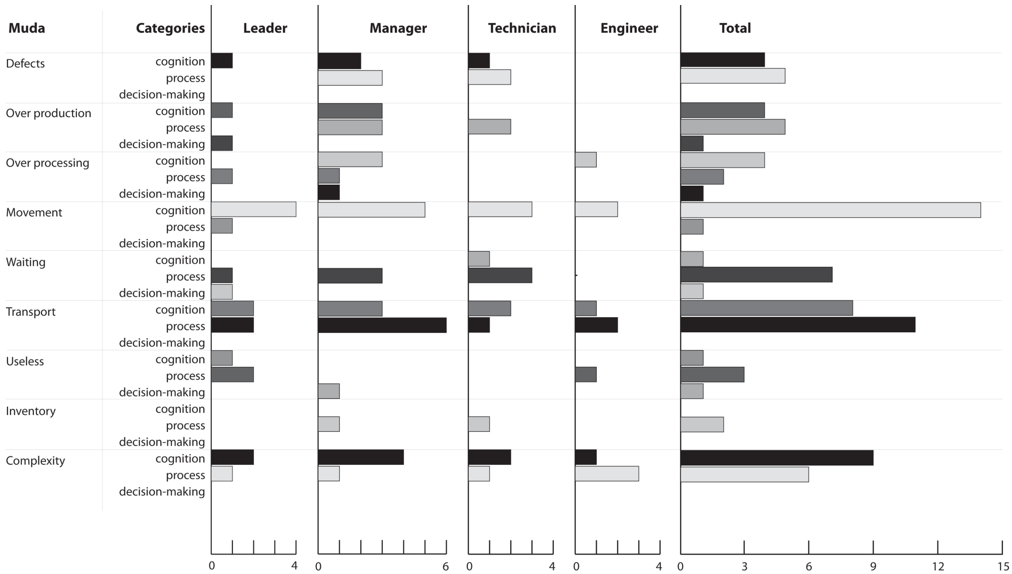


Figure 5.18. Identification of *MUDA* in Mechanical engineering Case Study (absolute numbers)

From the results derived from three case studies it was noticeable that:

- Some sources of *MUDA* are also referred as valuable by some of the interviewees for providing for example, *Flow* or leaps (i.e. pressure). Thus, the system of influence on designers' behavior that can lead to *MUDA* situations has a non-absolute negative effect, but can also have positive aspects of awareness, reflection and action to alternative trajectories.
- The study of how designers cope with *MUDA* through the identification of actions and drivers that constitute their *Value* systems can contribute to the awareness of *MUDA* situations in the culture and practice of design.

Without disregarding the fact that situations of *MUDA* can and should be minimized in design, other issues have raised from the results of the analysis:

- How far the study of *MUDA* situations is relevant to design and what role do they play in the causal mechanisms of the design process?

At this stage, the analysis and data collection were on-going processes. The research proceeded with empirical studies in other design disciplines. The studies described in 5.1 to 5.4, on the investigation of Lean Principles in design, facilitated the identification of different sources of *MUDA*, in dimensions such as, *execution, planning, outsourcing, change mind set* and *developing imagination* among others. A deeper immersion in the data provided the researcher with a better clarification of codes and clusters to start reducing possible overlapping between the categories. A second round of analysis of the selected and other quotes from the 25 interviews was accomplished. Definitions were reworked, based on a qualitative assessment of such clusters (Vieira et al, 2012a).

After many stages of iterative analysis, coding and clustering procedures, it was finally concluded with empirical evidence that, in design, the situations of *MUDA* differ from those of the manufacturing context. While in production the idea of *Value* relates to the final result of an expected procedure that can be optimized, in design, *Value* is defined at the same time that resources are absorbed during the creative process. The complete definition of *Value* is just accomplished in the end. Thus it is not possible to completely control resources in design, some *Value* loss and waste (*MUDA)* is inevitable.

At the same time, overlapping between the types of *MUDA* was identified while clustering the codes of designers' quotes. Other emerging clusters of actions related to interdependencies, assess but also transfer of information, defining quality and quantity in design results, and planning probability and anticipation were not matching with the types of *MUDA* and became dimensions of analysis. In addition, it was noticed that the terminology of the nine types of *MUDA* assumes a negative connotation.

- LT defines *MUDA* types based on what should be avoided (i.e. waiting, movement, over processing). However the sources of *MUDA* in design do not always lead to negative effects but also to positive consequences.

- The Lean terminology is related to the manufacturing environment. The direct application of *MUDA* types in the design context would not be suitable as a shared language of communication.

Therefore, in this thesis the transference of the *MUDA* concept into design does not assume connotation. From the analysis of interviewees' quotes, potential situations of *MUDA* have source in actions that went wrong, while in other quotes, the same actions avoid *MUDA* and uphold performance. A twofold outcome was identified from the same source of action, a critical aspect of *Value* loss, and a crucial aspect of remaining in *Flow*, or converting *MUDA* into *Value*. Two examples are given for the action of defining and how it can lead to opposite outcomes if taken excessively or if flexibility is adopted, and the action of defining is taken adequately.

> *'For example if you look at goals in the beginning of the project to make sure if you are in the same page as all the other stakeholders in the project, but if things are maybe too defined, too much, then you lose the freedom to go and try to find all types of solutions or approaches, so if they say that it has to be not more than 1 meter, and you design something that is way better than anything else but has 1,5 meters, it's too much defined.'*

In this quote the critical aspect relates to the possible *Value* loss, if a better solution is set apart by a strict and limiting definition of a measure.

> *'There is the color concern which is related to the emotions of the diverse contents' impression. Colors are the last thing to be defined and are one of the most important things because they're related with the feeling one has about the project, with the sensation we felt when all the contents were received. It's all about the right emotion and how we convey it, how the colors show it.'*

In this quote the crucial aspect relates with defining the adequate color that represents the intended emotion and meaning, if such action is taken with a flexible and adaptive process for an effective *Value* definition.

From the evidence that the influence of *MUDA* could have a twofold outcome, a positive or negative effect, these situations could not be named as

MUDA. As such influencing situations have a critical aspect of *Value* loss I have decided to call them *critical situations*. From this point forward, the research adopted an approach to the phenomenon of *MUDA* as *critical situations* in design, which sources also lead to *crucial actions* to cope with the circumstances.

This thesis proposes the Lean concept of *MUDA* as *critical situations* in design that can limit but can also challenge designers' behavior and performance. Therefore, the identification of sources of *critical situations* is in this research one of the drivers for the translation of the Lean Thinking philosophy in design research. Lean Thinking proposes the elimination of *MUDA* or its conversion into *Value*. The identification of what and how designers *Value* in *crucial actions* can provide the understanding of how to prevent or even transform *critical situations* into *Value.* From this point forward the research became interested in the phenomenon of *critical situations* and the characteristics of such circumstances either with negative or positive consequences.

Sources of Critical situations as Crucial actions in design

After the stages of investigating the Lean Principles through the analysis of interviews and meetings, the research returned to the topic of *MUDA*, now as *critical situations*. The analysis of meetings also helped to see that the sources of *MUDA* could also be actions to uphold performance. Therefore, the analysis of meetings was focused on the sources of situations that can bring a twofold outcome according to its helpful or not helpful influence. As previously mentioned, these situations were found to have a critical aspect that called for the identification of what could go wrong and a crucial aspect of what could be done to get things back on track. Designers might recognize a possible *Value* loss *(critical situation)*. If so, and solution is found, then designers are able to take *crucial actions* to avoid *Value* loss. If not, even if long-term *crucial actions* can be figured out, it remains a *critical situation*, as *Value* loss can happen. In addition, the absence of essential features in *critical situations*, makes designers searching for options through iteration, ignoring certain aspects or circumvent strict requirements, finding ways for better solutions.

As the difficulties in assessing *critical situations* in meetings were overcome a final categorization system derived from the semantic analysis of meetings and interviews. The analysis of meetings provided a better understanding of the nature of the activities per categories and led to a third round of analysis of the interviews and fine-tuning of the categorization system (Vieira et al., 2012b).

Data from interviews

From the analysis of interviews, the designers reflect and describe how they recognize the situation, its antecedents and consequences, positive and negative outcome and sometimes recognize the required actions for reaching an effective result (crucial actions). From the 582 quotes selected from interviews, two types of *critical situations* derived from the analysis of designers' interviews statements, which identification is explained and exemplified:

216 Critical Situations I (CS I) – correspond to designers' quotes describing how they recognize the situation, explain its cause, antecedents and consequences leading to positive or negative outcomes but no solution is provided, only the analysis of the circumstances. An example is transcribed.

> *'Main difficulties are the estimation of the value of construction. If we start a project this year at the present price of construction, if suddenly we just start to build the project next year, the price of construction will be different. We cannot have a total control of the construction. I had an example of a project budget for a certain value for construction that just started after 3 years, and then the client complained about it, ok, but I have nothing to do with that.'*

365 Critical Situations II (CS II) (critical situations with crucial actions) – correspond to designers' quotes describing how they recognize the situation, identify its antecedents and consequences, anticipate and explain actions to be taken to reach an effective result.

> *'We have huge risk sources because we deal with so many work fronts: several types of suppliers, several types of finishings of what we do, several types of equipment. They grow exponentially as we increase our work fronts.*

> *When we mention a museum (you already had the chance to follow at the meeting) the number of fronts is overwhelming: it's one supplier in 3Di, one animation in 3Di, the computer where that 3Di will run, the processor inside that computer, the display that will be connected to that computer, the piece of furniture where the display will be located, the scenography of that display, the design inside that display, the design outside that display…and who evaluates the quality of this? There must be a very attentive team and I believe this attention is only acquired through experience, through matureness. It's not something that any person becomes attentive overnight and suddenly quality is first grade, no it's not.'*

From the 365 transcripts of *Critical Situations* II (CS II), the analysis identifies:

404 Crucial actions (CA) – where designers state, do, anticipate or explain, what has to be done to reach an effective result.

After several stages of analysis of the characteristics of the 582 utterances a first categorization system was settled (Vieira et al., 2011b). The given examples only show some of the aspects inherent to *critical situations*, other aspects are further detailed with the explanation of the categorization system.

Data from meetings

The task to identify *Priority Issues* under *critical situations* in meetings revealed difficulties. Meetings showed that *critical situations* are complex to assess, once they occur in instances of evaluation that include multiple aspects of influence in decision-making such as iteration, interdependency and reviewing that can just be empirically assessed through observation. However, a *critical situation* is noticed when a designer recognizes and states that an essential feature is absent, does not work, or is not assured. The analysis of meetings helped to typify the *critical situations* in long-term and short-term once the recognition of *crucial actions* is achieved in distinct time span:

35 Long-term Critical Situations (LTCS) – noticed when a designer recognizes and states that an essential feature is absent, does not work, or is not assured and immediate solution is not found. Sometimes designers foresee the required long-term measures towards a final decision. An example is transcribed.

> *'Theodore: the nail sensor when introduced in the cell has the effect "movie knife". It's expensive.*
>
> *Peter: in x-ray sensors the time slots are long. Light needs to be isolated otherwise it might not work. How are we going to give feedback? How does it physically stop?*
>
> *Theodore: What are the basic consume numbers? The sphere resistance is not enough, and for now it's lose when it returns.*
>
> *Daniel: yes.*
>
> *Jonas: We have to know what mechanisms we can use within the budget. See what we can produce, which drawings can we assume based on materials and production solution.*
>
> *Francis: they (the client) liked very much the drawing with the nail being introduce into the cell.*
>
> *Sebastian: the client wants the cell a bit more round. The nail sensor introducing the cell is decided, but now, how can we do it?*
>
> *Peter: we have to test the sphere rubbing. It can stop the user. Remember that previous work?*
>
> *Gabriel: it's more interesting to have the zoom as an effect. We have to make tests with the sphere.'*

26 Short-term Critical Situations (STCS) – are noticed when a designer recognizes that an essential feature is absent, does not work, or is not assured, and the necessary actions are identified (crucial actions). An example is transcribed.

> *'Sofia: So, are we going to exhibit artwork?*
>
> *Horace: Do we ave artwork pieces to exhibit?*
>
> *Rodrigo: artwork…*
>
> *Patrick: that face says no (Rodrigo's face)*
>
> *Alex: we can, we have for example, things from the foundation old factory that don't request insurance and are abandoned.*
>
> *Horace: pieces that don't request security or insurance.*
>
> *Rodrigo: Sofia's question is answered, then.*

Horace: besides, there are no conditions to assure thermic amplitude to have valuable pieces of artwork in this place.'

Results derived from the analysis of the 29 Short-term critical situations (STCS):

36 Crucial actions (CA) – where designers say what to do for an effective result.

The given examples show absent (sphere resistance) or not assure (security and insurance of artwork) aspects of critical situations. The same examples are further detailed with the explanation of how *Value* is prioritised in *crucial actions*. The results reported in this study derived from the semantic analysis of data gathered from meetings and interviews (Table 5.25).

Table 5.25. Short and Long-term critical situations, CSI, CSII, and crucial actions per case study

Case Studies	**Total critical situations across the meetings**								
	M1	M2	M3	M4	M5	M6	M7	M8	Total
Graphic	5	2	1	1	1	1	-	-	11
Interaction	4	4	0	1	2	2	5	-	19
Architecture	7	2	0	0	1	0	0	-	10
Engineering	4	2	1	1	2	1	4	7	22
Total	20	10	2	3	6	4	9	7	61
	Short-term critical situations								
	M1	M2	M3	M4	M5	M6	M7	M8	Total
Graphic	1	1	0	1	1	1	-	-	5
Interaction	2	3	0	0	0	1	2	-	8
Architecture	5	1	0	0	1	0	0	-	7
Engineering	2	0	0	1	1	0	1	1	6
Total	10	5	0	2	3	2	3	1	26
	Crucial actions in Short-term critical situations								
	M1	M2	M3	M4	M5	M6	M7	M8	Total
Graphic	1	1	0	1	2	2	-	-	7
Interaction	3	4	0	0	0	1	2	-	10
Architecture	1	7	0	0	1	0	0	-	9

Engineering	2	0	0	1	3	0	3	1	10
Total	7	12	5	3	7	3	5	1	36
	Long-term critical situations								
	M1	M2	M3	M4	M5	M6	M7	M8	Total
Graphic	4	1	1	0	0	0	-	-	6
Interaction	2	1	0	1	2	1	3	-	10
Architecture	2	1	0	0	0	0	0	-	3
Engineering	2	2	1	0	1	1	3	6	16
Total	10	5	2	1	3	2	6	6	35

	Critical situations across the interviews			
	Critical situations II	Crucial actions in CSI	Critical situations I	CSI+CSII
Graphic	66	69	35	101
Interaction	37	43	48	85
Architecture	89	100	37	126
Engineering	94	103	53	147
Industrial	79	89	43	122
Total	365	404	216	582

Protocol analysis studies usually report results from small samples ranging from a few minutes to one or two hours. However, in the practice of design, projects last a few weeks or months. Although data consists of sets of six to eight sequential meetings, located in critical stages of importance to decision-making, *critical situations* are not so frequent in meetings. The study of *critical situations* would have been difficult with single meetings.

The advantages of sequential meetings as source of data became evident: naturally occurring design activity in authentic settings in a time span that allows studying how *Long-term critical situations* evolve towards completion. The number of *critical situations* decreases along the meetings in the Graphic design and Architecture case studies, and increases in the last meetings of the Interaction design and Mechanical engineering case studies.

The *Short-term critical situations* have lower incidence in the meetings of the Graphic design, Architecture and Engineering case studies and increases in the meetings of the Interaction design case study. The *Short-term critical situations* have higher incidence in the first meeting of each case study. In the following the categorization system is described and illustrated with results across the case studies.

As further described, triangulation was possible to some of the categories, while the complete categorization system needs an extended sample of data for validation.

Categorization System: A Meta-level Behavior Framework

The investigation of *MUDA* in design leads to a categorization system of sources of *critical situations* and *crucial actions* in design, based on results from the interviews and meetings across the case studies.

The seven invariant categories are based on the identification of the nature of physical and mental actions that can lead to a twofold outcome. The sub-categories represent the challenges that design practitioners face in order to continue, keep *Flow*, and pursue their objectives. Aspects of the seven main categories and a positive and negative behaviour illustrate the circumstances (Table 5.26). All the sources of *critical situations* can be found in circumstances that make decisions vulnerable that might do not intend side and long-term effects, as situations of potential *Value* loss, where risk and uncertainty take place. Therefore, being aware of sources of *critical situations* and *crucial actions* to cope with the circumstances, structuring its sources became a contribution of this doctoral research, essential to support practitioners, students and design educators. Undertaking these actions under a successful or less successful behaviour leads to different outcomes.

This categorization system is a meta-level behavior framework to support design practitioners in these circumstances and calls for the need to uphold performance. The definition of each category is provided and followed by examples.

Table 5.26. Sources of *Critical situations* and *Crucial actions* in design

Critical situations and Crucial actions in Design			
Categories of Sources	**Sub-categories of Challenges**	Examples of observed less successful behaviour in critical situations	Examples of observed successful behaviour in crucial actions
Dosage	**Adequacy**	Missing criteria	Look for essential criteria
	Balance	Over/ under dosage	Make things matching
Planning	**Probability**	No risk evaluation	Contingency planning
	Anticipation	No view of the future	Foreseeing opportunities
Framing	**Orientation**	Difficulty to choose	Reflected choice
	Focus	Stuckness	Convergence
Information Assessment	**Surprise**	Missing opportunities	Opportunistic procedure
	Knowing	Clients that do not know what they want	Look for information
	Transparency	Difficulty to grasp the features of a problem	Searching for indicators
Information Transfer	**Communication**	Confirmation bias	Transparent communication
	Exchange	"Tunnel view"	Awareness of the need for sharing information
	Documentation	Not keeping record of sub-results	Keeping record of sub-results
Interdependency	**Interfaces**	Acting without reference to others involved	Awareness of the different interfaces involved
	Suspension	Missing feeling of competence	Take time for decisions and keep in mind long and short term consequences
Envision	**Open up solutions**	Difficulty to think into the future	Generating alternatives
	Representation	Difficulty to represent a concept	Providing clear examples, good graphics and visual proposals.

Dosage – refers to the need to find adequacy (enough in quantity or good enough in quality for a particular purpose or need) or balance (emotional, economical, aesthetical, or negotiable stability) in the quantity and quality of different activities and measures, in order not to overdo or be underdone. An example of *Balance* is described.

> *'Other times the client doesn't give us all the contents, he just gives a general idea, and when we finally have them all we realize they are insufficient for the areas we reserved. It's again the same problem of the areas. All these issues change the ongoing work and the final result turns out very different from what we initially projected. It's also this but many times the problem comes from the budgets.'*

Planning – refers to situations which need for an action plan for the future regarding the extent to which results are likely (probability), and the extent to which something is expected or predictable and take action in order to be prepared (anticipation). An example of *Anticipation* is described.

> *'If it's a bad or annoying client then we must find ways to communicate with him and pass the message of what we want to accomplish. You have to be prepared in advance to deal with these situations. It's like driving on a winding road, if the turns are dangerous then you must foresee it and drive carefully. If I know this client and I'm aware that I'll have problems with him, I must change my usual approach and find a new carefully thought way to be able to communicate with the client.'*

Framing – refers to situations that hinder or provide orientation (direction to proceed) and focus (concentrating interest, to adapt or adjust so that things can be seen clearly), that need to be framed or reframed. An example of *Orientation* is described.

> *'Many times you have clients that are not able to define exactly what they want, or the program is defined and then later in a first analysis a contradiction is found, or what is though to do in that place doesn't work or works badly. Thus, it is necessary to confront him and say, "should we think about this in other terms" "wouldn't be better to redefine?" I think this is our obligation, if someone asks us for the work we should let him know when initial things are not well thought, "In my opinion I don't think this is well thought, we can do it this way".'*

Information assessment – refers to the awareness of the relevance of a situation that shows the absence or latest information and that relate to: moments of surprise (denoting something made, done, or happened unexpectedly), transparency (difficult to perceive or detect) and knowing (what is known or not about facts, information, and skills acquired by a person through experience or education), which create ambiguity and uncertainty that can hinder the process but can also be beneficial to generate alternatives and overview. An example of *documentation* is described.

> *'Documenting is a strongest point, I think it sort of hinders my flow in designing things and I want to continue on things and if I do reflect it's, I've learned that we should reflect on things but it's also holding me back more, because then I think, I could be writing down things, more than I already did.'*

Information transfer – refers to situations where the transference of information requires to deal with different challenges such as: communication (the successful conveying or sharing of information, ideas, feelings, news, through the means of sending or receiving information), exchange (an act of giving or doing something to somebody and receiving something in return) and documentation (the act on recording material that provides official information, evidence or that serves as a record). An example of *Communication* is described.

> *'I think is fundamental that, first, that the client understands the project, floor, facades and section drawings, showing mock-ups, 3D images or showing similar aspects of the built projects. It is essential that the client understands what the architect wants to do. This is not always easy to do.'*

Interdependency – refers to situations where the need to establish or undo interdependencies, is made through the creation and recognition of interfaces (a point or moment where two systems, subjects, organizations, etc., meet and interact, such as people, companies, expertise, software, technical limitations) or suspension (the action of suspending someone or something or the temporary prevention of something from continuing or being in force or effect). Two examples of *Suspension* are described.

'The client often takes too long to evaluate the project and have a final decision. We have book covers that are standing by for over a year waiting for a client's decision.'

'It's usually the contents not arriving on time. There's always an excessive optimism when delivery times are evaluated. Delivery times from the clients to us and from us to our suppliers. Most of our suppliers are excellent people and they deliver on time, which is great. It's important to have suppliers you can trust because many of them suffer...I see it, I'm always contacting them. Delays are really the ones to blame, people think optimistically they can do one thousand and one things at the same time and then they can't deliver on time and then...'

Envision – refers to situations that ask for opening up solutions, imagining future possibilities for the design goal, solution or sub-solutions, taking different perspectives, and representation, giving form to mental images or making something visible to the eyes and feasibility assessment. Such situations can hinder or further the design process regarding the extent to which such mental or physical images of solutions are created with flexibility, taking different perspectives, providing a wider ideation space to be unfolded and solutions to come into view. An example of *Open up solutions* is described.

'we've done so many over the last years...For instance, (it was something you witnessed) at a certain time Horace was saying that the spiral would unfold to this side and I said "but that way the reading will be reversed". He wasn't imagining it, he likes to enter a certain space and read from left to right and I was seeing that in that particular place between the pillars it was possible to unfold perfectly to the other side. I said it and he agreed. That's it, it just happened, sometimes we don't have much time and things...At that time I intervened and really helped, it wasn't nothing new, it was just a little push to help things move on...I have already been through these situations.'

Invariants

Results from the analysis of 582 quotes from interviews, showing incidence of L*ong-term critical situations*, *Short-term critical situations* and *crucial actions* per category are illustrated in Figure 5.19.

Similarly to the stage of analysis previously reported (Vieira et al., 2012a) results show that the sub-categories of *Interfaces, Focus, Orientation* and *Adequacy* show high incidence as sources of *critical situations* and therefore the need to cope with such circumstances. As example, the antecedents of *critical situations* regarding two of the categories with highest incidence are described.

Antecedents of *critical situations* of *Interdependency* relate to the following codes, *need to experiment design solutions dependent on the execution of others*, such as in situations of *outsourcing*, the *choice or awareness of the persons that will act as interfaces*, such as in contact with the client.

Antecedents of *critical situations* of *Framing* relate to the following codes, *need to structuring information, structuring what is wanted, to provide a clear vision of the design goal, framing strategies, framing the solution on what will remain, framing the core of the solution for a more structured and natural development, framing to eliminate superfluous things around the problem, reframing to reconsider unnoticed aspects, or aspects judged in a biased way*, or *framing to see the whole of the parts.*

From the analysis of the interviews, all the sub-categories of challenges show frequency of long-term and short-term *critical situations* and *crucial actions*.

The sub-categories of *Interfaces* and *Focus* show the highest incidence as sources of *critical situations* I. Therefore results indicate the importance of coping with these sources of *critical situations*.

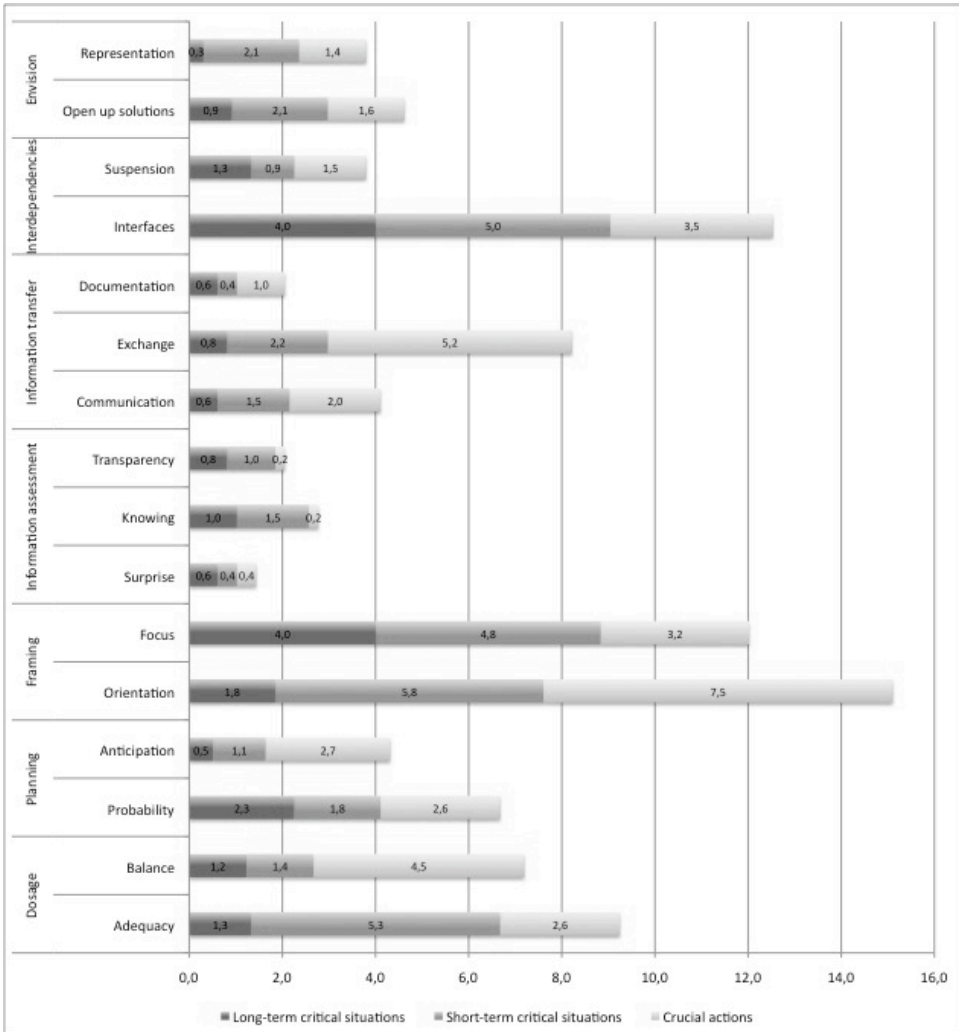


Fig 5.19. Relative % of the incidence of *Critical Situations* I and II and *Crucial Actions* per category based on the analysis of interviews across the five case studies

From the analysis of the 365 utterances of *critical situations* II, results on the incidence of *crucial actions* per category show that the sub-category of *Exchange*, *Orientation* and *Balance* has high incidence and relates to codes such as, *Requesting information*, *searching for other design trajectories*, *balancing costs* and *Stating "no"*. Designers described known solutions to cope with influential circumstances based on these sources of actions. For example, the sub-categories of *Suspension*, *Documentation*, *Communication*, *Anticipation* and *Probability*, have higher incidence as *crucial actions* than sources of *critical situations.*

Results from the analysis of 61 *critical situations* identified in meetings, show incidence of long-term and short-term *critical situations* and *crucial actions* as illustrated per category in Figure 5.20. Results show that the sub-categories of *Interfaces*, *Focus*, *Knowing* and *Adequacy* show higher incidence as sources of *critical situations* and therefore the need to cope with such circumstances. Results show a percentage of *Long-term critical situations* – without the description of coping actions – across 14 categories. Thus, these situations ask for further study and development of coping strategies. The sub-categories of *Adequacy*, *Focus*, and *Anticipation*, followed by *Orientation*, *Interfaces* and *Representation* show high incidence as *crucial actions*, meaning that such clusters are known solutions for designers in coping with influential circumstances. Codes are related to, *proposing alternative solution, reducing discrepancy, measuring features, searching for a trust source, setting a strategy, reducing error, preparing drawings.*

Seven of the sixteen sub-categories of challenges show occurrence of *Long-term critical situations*, *Short-term critical situations* and *Crucial actions* across the case studies.

As previously mentioned, *critical situations* are less frequent in design meetings than in interviews, therefore, a wider sample of meetings would be necessary to validate the complete categorization system.

Other invariants derived from the analysis across the case studies are further listed and described. Such invariants regard aspects of *critical situations, crucial actions* and interaction procedures.

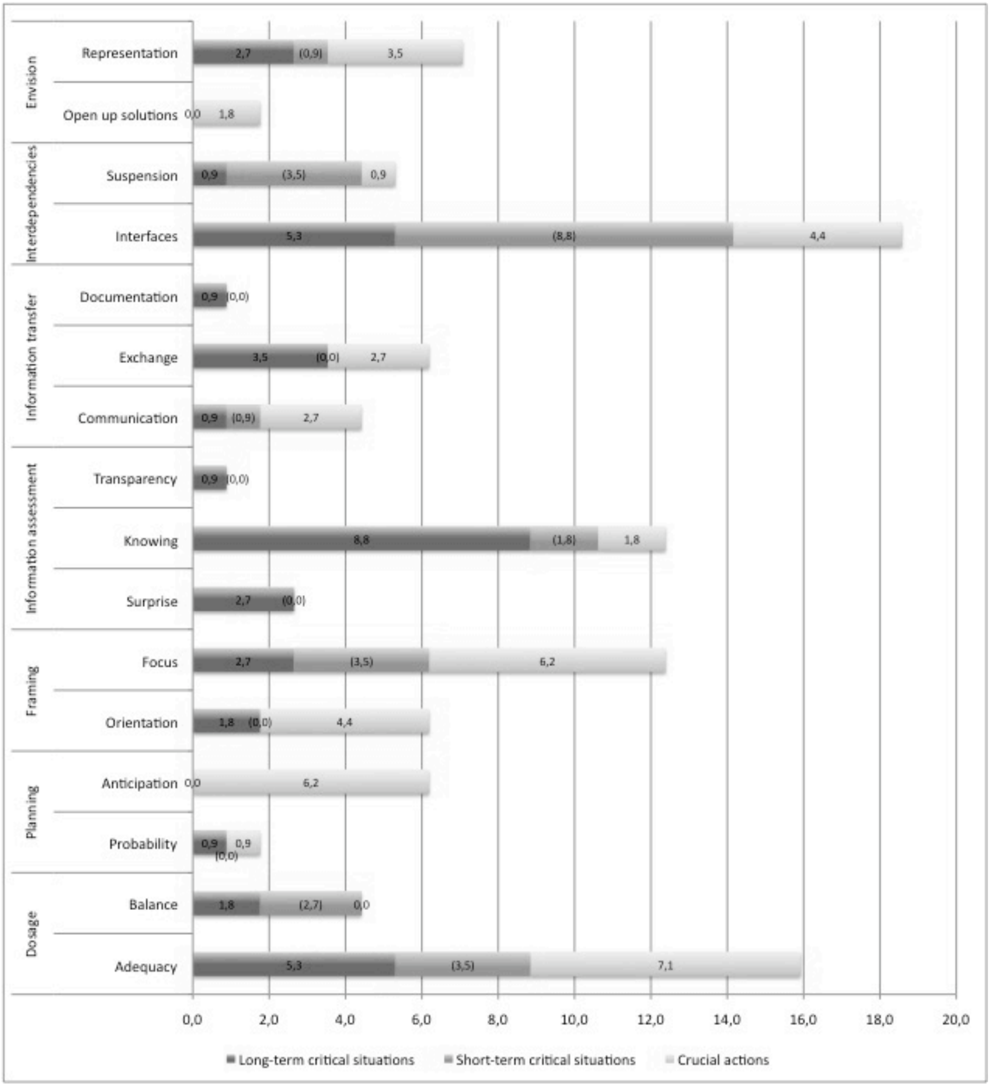


Fig 5.20. Relative % of the incidence of Long-term and Short-term *Critical Situations* and *Crucial Actions* per category based on the analysis of meetings of four case studies

Priority Issues under *critical situations* brought into discussion and description derived from four sources:

- Individual
- Team
- The design subject
- External influences

Critical situations are many times unnoticed or disregarded, therefore, the importance of an enduring awareness. Iteration processes have the capacity to make unnoticed critical *Priority Issues* become apparent and therefore prioritized for discussion. The *critical situations* fail to be noticed when they were:

- Never experienced
- New
- Assumed as inherently solved
- Its core issue is not yet unveiled
- Non-transparent

Critical situations and *crucial actions* can occur and influence the following views of the design process towards the completion of the result:

- Goal
- Direction
- Ideation
- Detail
- Teamwork
- Planning
- Conceptualization

The *critical situations* are noticed when an element of the team recognizes and states that an essential feature is not:

- Existing
- Working
- Assured

The individual starts with a question based on a doubt or update request regarding the essential feature, for example, asking *what's missing? Critical situations* emerge in the design process as a consequence of introduced *Priority Issues* derived from management demands that relate to:

- Priority
- Emergency

Crucial actions emerge in the design process as consequence of instances of evaluation of *Priority Issues* where the discussion leads to *crucial actions* to be taken based on common agreement. Such circumstances relate to:

- Challenge
- Absence of essential features
- Value judgment
- Decision-making

Although challenge (meaning, a call, contest, an objection or query, a task or situation that tests someone's abilities with an implicit demand for proof) marks the crossroad for the identification of a critical *Priority Issue*, what is specific of *critical situations* is the recognition of *non-existing, non-working* or *non-assured* essential features in the design process. This doctoral research proposes the definitions of *critical situations* and *crucial actions* in design (Table 5.27 and 5.28).

Table 5.27. Characteristics of *Critical situations*

Critical Situations			
Derivation	**Cause of overlook**	**Influence**	**Elements**
• Individual • Team • The design subject • External influences	• Never experienced • New • Assumed as inherently solved • Its core issue is not yet unveiled • Remains non-transparent	• Goal • Direction • Ideation • Detail • Teamwork • Planning • Conceptualization	• Challenge • Absence of essential features • Value judgment • Decision-making
Definition	The absence of essential aspects of the design process is identified and prioritized for team discussion delaying decision-making in short and long-term.		

The identification of needs and causes of overlook sign the detection of *critical situations* leading to instances of *Value* judgment for decision-making. C*rucial actions* comprise the identification of the challenges (Table 5.26) to overcome the source of a *critical situation* as behavior signs to stand up for in instances of *Value* judgment, where *Value* is prioritized and drivers for decision-making identified.

Table 5.28. Characteristics of Crucial actions

Crucial Actions			
Derivation	**Cause of overlook**	**Influence**	**Elements**
• Team • Individual • External influences	• Never experienced • New • Assumed as inherently done	• Goal • Direction • Ideation • Detail • Teamwork • Planning • Conceptualization	• Hold against failure • Challenge identification • Assure continuity • Value priority • Decision-making
Definition	The identification of the challenges to overcome the source of a *critical situation* is made based on individual or team *Value* judgment and converges to the dentification of *Priority Value(s)*, and drivers for decision-making constituting actions to be taken in short and long-term for an effective result.		

Variants

Case studies of technology-based design approach such as the Interaction design and Mechanical engineering show higher incidence of *long-term critical situations*, while case studies of rule-based design approach of clear identified tasks and competences as Graphic design and Architecture show lower incidence of *long-term critical situations*, both in meetings and interviews. The innovation-based design approach of the SME of interactive design solutions, a company operating in the emergent discipline of Interaction design, which body of knowledge asks for more structure, organization, development and management abilities naturally shows the lowest incidence of *short-term critical situations* and *crucial actions*. Although operating in an internal transdisciplinary design environment this company still needs to reach the level of awareness and managerial aptitude of other cases studies working in internal inter and multidisciplinary environments as the Architecture and mechanical engineering, respectively. This is reflected in the high incidence of *crucial actions* in the category of *Interdependency*, sub-category *Interfaces*, and *Framing*, sub-categories of *Orientation* and *Focus*. From the analysis of the statements of *short-term critical situations* some *crucial actions* were described as patterns of sequence of two to three actions (further illustrated in Chapter 6). Table 5.29 illustrates results from the analysis of interviews per categories across case studies in absolute numbers.

Table 5.29. Critical situations I and II, and crucial actions from interviews across categories per Case Study: Graphic (G), Interaction (I), Architecture (A), Mechanical engineering (M), Industrial design (Id)

Categories	**Sub-categories**	**Critical situation II**					**Crucial action**					**Critical situation I**					**Total**	
Source	**Challenge**	**G**	**I**	**A**	**M**	**Id**	**G**	**I**	**A**	**M**	**Id**	**G**	**I**	**A**	**M**	**Id**	ST	LT
Dosage	Adequacy	12	9	8	11	12	12	11	8	11	12	2	4	2	2	3	***52***	***13***
	Balance	4	2	2	4	2	4	2	2	4	2	0	4	1	2	4	***14***	***11***
Planning	Probability	2	2	3	6	5	2	2	3	7	6	3	7	1	7	4	***18***	***22***
	Anticipation	2	2	5	2	0	3	3	5	5	0	1	1	1	1	1	***11***	***5***
Framing	Orientation	9	3	20	10	14	10	3	20	10	17	3	5	5	3	2	***56***	***18***
	Focus	5	9	11	12	10	5	9	20	14	11	3	9	8	11	8	***47***	***39***
Information Assessment	Surprise	1	1	1	0	1	1	1	1	0	1	1	0	3	1	1	***4***	***6***
	Transparency	4	0	1	5	0	4	0	2	5	0	0	2	2	3	1	***10***	***8***
	Knowing	2	0	2	5	6	2	0	3	5	9	5	1	1	2	1	***15***	***10***
Information transfer	Communication	0	2	4	4	5	0	2	4	4	6	2	0	0	4	0	***15***	***6***
	Exchange	3	1	3	10	4	3	1	3	10	5	3	0	2	2	1	***21***	***8***
	Documentation	0	0	0	3	1	0	0	0	3	1	1	1	1	1	2	***4***	***6***
Interdependency	Interfaces	12	3	14	11	9	12	3	14	13	9	7	12	6	6	8	***49***	***39***
	Suspension	5	0	1	2	1	5	0	1	2	1	3	1	0	8	1	***9***	***13***
Envision	Open-up solutions	4	1	7	4	4	5	4	7	5	4	1	0	4	0	4	***20***	***9***
	Representation	1	2	7	5	5	1	2	7	5	5	0	1	0	0	2	***20***	***3***

The case study of the Industrial design graduating students, which design approach is rule-based in a learning environment, shows a balanced number of *critical situations* and *crucial actions*, with higher incidence in the same categories, *Framing* and *Interdependency*, but also *Dosage*, in the sub-category of *Adequacy* and *Information assessment*, in the sub-category of *Knowing.* Students show more difficulties in the category of *Envision*, and low or complete unawareness to *critical situations* and challenges such as, *Transparency*, *Anticipation*, and *Suspension*, which suggest the usefulness of including the framework in design education.

Designers' *Priority Value* in Crucial actions

Study IX shows higher incidence of *critical situations* in the first or last meeting of the observation period (Table 5.25). Study X investigates how designers' prioritize *Value* in *crucial actions* in the first meeting of each project. Table 5.30 illustrates the first meeting topic, stage, time, team members' presence and background per case study.

Table 5.30. Overview of the first meeting of each design project per case study

Case Study	Graphic	Interaction	Architecture	Engineering
Meeting	1	1	1	1
Duration	2h: 21 min	1h: 30 min	1h: 47 min	1h: 06 min
Topic	First concept ideas	Discussion of feasibility of concept ideas	Context analysis, First concept ideas	Detailed discussion of specifications and solutions
Stage	**Development of ideas**	**Development of ideas**	**Context analysis**	**Analysis of requirements**
Team	Client project manager	Leader/Art Director	Leading architect	Leading researcher
	Client design manager	Ergonomics designer	Architect	Electronics Engineer
	Leading designer	Illustrator	Detail Architect	Software Engineer
	Graphic designer	Programmer	Infrastructure Architect	Technician
	Designer 1 (Producer)	Multimedia designer		
		Creative designer		
		Project manager		
		Project manager abroad		
		Copywriter		
		Electronics engineer		
		Mechanics engineer		

The study attempts to investigate and understand how designers prioritize *Value* in these circumstances through a more detailed analysis of the transcripts, audio and video files of the first meetings of each set. The study investigates the 20 *critical situations* introduced for discussion in the first meetings of the four design projects. Each *critical Priority Issue* was mapped according to its instances of *Value* judgment and iteration across the meeting (Table 5.31).

Table 5.31. Frequency and iteration of critical situations of meeting 1 across the meetings per case study

Case Studies		**Situation**		**Frequency per meeting**								Total Iter.
Design	**Priority Issue**	STCS	LTCS	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
Exhibit	Financial allocation		S1	3	2	6	-	-	-			*10*
	Access to content		S3	5	2	17	4	5	-			*32*
	Content definition		S7	8	-	4	-	1	-			*12*
	Information exchange		S15	1	1	1	-	2	-			*4*
	Original objects	P4		1	-	-	-	-	-			-
Total		*1*	*4*									
Interactive solutions	New interactive design solution		S4	3	-	1	1	1	1	1		*7*
	Detail		S5	1	2	-	-	-	-	-		*2*
	Unfocused team element	S6		1	-	-	-	-	-	-		-
	Reporting	S7		1	-	-	-	-	-	-		-
Total		*2*	*2*									
Train Interface	Awareness to construction	S10		4	1	-	-	-	-	-		*4*
	Circulation norm/constraints	S13		1	-	-	-	-	-	-		-
	Railway norm/constraints	S15		2	-	-	-	-	-	-		*1*
	Line of argumentation		S16	5	-	-	-	4	1	-		*9*
	Information organization	S21		1	-	-	-	-	-	-		-
	Inaccurate drawings		S26	8	2	-	-	-	-	-		*9*
	Information transfer	S28		2	-	-	-	-	-	-		*1*
Total		*5*	*2*									
Robot	Bug	B		1	1	-	-	-	-	-	-	*1*
	Space box for components		S11	1	2	-	3	-	-	-	-	*5*
	Demo experiment	S18		1	-	-	-	-	-	-	-	-
	IMU specifications		S19	1	2	3	1	-	-	3	-	*9*
Total		*2*	*2*									

Priority Issues under *critical situations* relate to the following matters: *access*; *definition and organization of information content*; *financial allocations*; *creating lines of argumentation*; *coping with norms, constraints and conditions*; *rigor and detail*; *information exchange and report*; *new design solutions*; *unexpected issues*; *feedback from experiences*; and highly interdependent issues.

The *critical situations* from the first meeting of the Graphic design project show higher incidence of *Long-term critical situations*, and the Architecture design project shows higher incidence of *Short-term critical situations.*

Short-term critical situations can have influence in the team performance and long-term consequences and side effects, while *Long-term critical situations* are based in highly interdependent design issues.

The analysis shows that *crucial actions* are not just taken in *Short-term critical situations* but also in some of the *Long-term critical situations* as it follows:

8 Long-term Crucial actions (LTCA) – where designers foresee the required long-term actions towards a final decision.

10 Short-term Crucial actions (STCA) – where designers do and say what has to be done for taking an immediate decision to reach an effective result.

From the analysis of the *crucial actions* the following elements were identified: c*hallenges* to overcome; *Priority Value(s)*; *drivers* for decision-making; and actions. Table 5.32 illustrates the elements of *crucial actions* taken in the *critical situations*. Two analysis of the transcripts from the meetings illustrate *short* and *long-term crucial actions*. The first example illustrates a STCA from the design of the exhibit, more precisely in the design issue: original objects (P4),

> *'Sofia: So, are we going to exhibit artwork? (Pull* mechanism*)*
>
> *Horace: Do we have artwork pieces to exhibit?*
>
> *Rodrigo: artwork…(*source of *critical situation: dosage (*MUDA*); challenge:* economic *balance (Pull* element*))*
>
> *Patrick: that face says no* (Rodrigo's face).

Alex: *we can, we have for example, things from the foundation old factory that don't request insurance and are abandoned. (Priority Values: reuse of objects; economic (Value))*

Horace: *pieces that don't request security or insurance*. (Driver of *Priority Value* for decision-making: *economic limitations (Flow))*

Rodrigo: *Sofia's question is answered, then.* (Decision plus action: source of *short-term crucial action: dosage; challenge: adequacy*, looking for suitable objects in the old factory *(Value Stream)).*

Horace: besides, there are no conditions to assure thermic amplitude to have valuable pieces of artwork in this place.' (absent features)

The second example illustrates a LTCA from the design of interactive solutions, more precisely in the *Priority Issue*: New interactive design solution (S4),

'Theodore: the nail sensor when introduced in the cell has the effect "movie knife". It's expensive. (Pull mechanism)

Peter: x-ray sensors time slots are long. Light needs to be isolated otherwise it might not work. How are we going to give feedback? How does it physically stop? (source of critical situation: interdependency (MUDA); challenge: interface (Pull element))

Theodore: What are the basic consume numbers? The sphere resistance is not enough, and for now it's lose when it returns. (absent features)

Daniel: yes.

Jonas: We have to know what mechanisms we can use within the budget. See what we can produce, which drawings can we assume based on materials and production solution. (Priority Value: essentials)

Francis: they (the client) liked very much the drawing with the nail being introduce into the cell. (Driver of *Priority Value* for decision-making: *client expectations (Flow))*

Sebastian: the client wants the sphere a bit more round. The nail sensor introducing in the cell is decided, but now, how can we do it? (Decision)

Peter: we have to test the sphere rubbing. It can stop the user. Remember that previous work?

Gabriel: it's more interesting to have the zoom as an effect. We have to make tests with the sphere.' (action: source of *long-term crucial action: envision; challenge: representation (Value Stream)).*

Table 5.32. Elements of *Crucial actions* in *Critical Situations* (STCS, LTCS) of the first meeting across the Graphic (G) and Interaction design (I), Architecture (A) and Mechanical engineering (M) case studies

Cs	*MUDA*	**Short-term Crucial Actions**			
		Pull	*Value*	*Flow*	*Value Stream*
	STCS	**Challenge**	**Priority *Value***	**Driver for decision-making**	**Action**
G	P4	Balance	Reuse of objects	Economic limitations	Stating "no"
I	S6	Focus	Dynamics	Client expectations	Searching for other perspective
I	S7	Communication	Transparency	Emotional evaluation	Communicate nonavailability
A	S10	Adequacy	Coherence	Fine-tuning design features	Measuring features
A	S13	Adequacy	Ethics	Challenging opposition	Defining disruptive solution
A	S15	Adequacy	Co-existence	Context conditions	Reducing discrepancy
A	S21	Adequacy	Well-being	Challenging opposition	Defining disruptive solution
A	S28	Probability	Essentials	Economic limitations	Setting a strategy
M	B	Interface	Ethics	Optimization	Searching for a trust source
M	S18	Interface	Rigor	Optimization	Reducing error
Cs	***MUDA***	**Long-term Crucial Actions**			
		Pull	*Value*	*Flow*	*Value Stream*
	LTCS	**Challenge**	**Priority *Value***	**Driver for decision-making**	**Long-term action**
G	S1	Probability	Co-existence	External conditions	Reducing ambiguity
G	S3	Knowing	Essentials	Designer expectations	Searching information content
G	S7	Open up solutions	Essentials	Client expectations	Proposing alternative solution
G	S15	Exchange	Coherence	Association with other projects	Requesting information
I	S4	Interface	Essentials	Client expectations	Having the zoom as an effect
I	S5	Communication	Transparency	Simulation	Reducing contradictions
A	S16	Adequacy	Essentials	Challenging opposition	Defining alternative solution
A	S26	Suspension	Essentials	Knowing something is wrong	Reducing error
M	S11	Representation	Transparency	See things matching	Preparing drawings
M	S19	Adequacy	Essentials	Economic limitations	-

In *Long-term critical situations*, actions taken are less due to the need to suspend decision; *Long-term critical situations* evolve based on the identification of absent features, and reducing or increasing uncertainty in the several iterations. In *short-term critical situations*, *crucial actions* relate to anticipation strategies to cope with constraints and make essential features prevail, immediate risk-assessment and information exchange protocols. The analysis show that iteration of *critical situations* is a recursive process in design meetings essential to absorb latest information, identify drivers, priority, reduce uncertainty, identify risk, change, and actions that lead to the path to follow. Such elements are in agreement with some of the sub-categories of the categorization systems developed in this research.

Long-term crucial actions relate to accessing information and knowledge, developing argumentation and solving financial management tasks. *Long and short-term crucial actions* entail four elements: a challenge (*Pull* element), a *Priority Value* (*Value* element), drivers of *Priority Value* for decision-making (*Flow* element), and actions (*Value Stream* element). Designers reflect on what they are doing, and figure out what can be done. There is an underlying concern with competent action to assure a certain trajectory. Some evidence raised the proposition that the source of *MUDA* varies in the several iterations of the same *Priority Issue*.

Based on the results of this doctoral research, a pattern of *crucial actions* in design is depicted in Figure 5.21. In design, Lean Principles take the illustrated sequence as elements of designers' behavior. The present pattern can serve as a guide to improve designers' performance.

Figure 5.21. Pattern of crucial actions in design: Lean principles sequence as elements of behavior.

Summary

Studies VIII, IX and X represent the ultimate efforts to identify *MUDA* in designing. The categorization system of *critical situations* and *crucial actions* in design was presented to the panel of evaluation for feedback on a Likert scale based questionnaire (see Appendix B). Results show an agreement of 83,8% with the categorization system. Average of the 16 sub-categories is 4,2 (1-5). The average of each of the five categories are over 4 to 4,3. The average of importance attributed to the seven categories is 5,2 (1-6), all the seven categories over 5. The inter-rater reliability test shows an agreement of 78% of first and second level categories. Non-agreement relates to 12% of overlapping between the categories of *planning, information transfer* and *assessment.* The researcher did not identify sequences of *critical situations* and *crucial actions* but one source for quote. However, in sequences of *critical situations* the research identified the last source of the critical aspect as consequence, and in sequences that ended with *crucial actions*, its source was the identified one.

The studies provided partial validation of the categorization systems based on one or two sources of data and feedback from the Likert scale based questionnaires. Research sub-questions are partially answered. The general findings of this chapter are illustrated in table 5.33. By now, it is evident that a wider sample of data is necessary to complete validation. However, the contribution of this thesis does not aim so much to achieve validity and reliability, but to outline directions for research on the translation and extension of the Lean Principles in design. From the investigation of the Lean Principles of *Value, Value Stream*, *Flow*, *Pull* and the concept of *MUDA* in design the following invariants are asserted:

- Categories of *Value* for designers.
- Categories of designers' approach.
- Categories of drivers of *Priority Value* for decision-making.
- Categories of *Priority Value* in design meetings.
- *Flow* diagram of interaction in meetings.
- *MUDA* in design as *critical situations.*

- Categories of sources of *critical situations* and *crucial actions* in design.
- Characteristics of *critical situations.*
- Characteristics of *crucial actions.*

Table 5.33. Overview of research questions, dimensions of analysis and results from the studies across the Lean principles, *MUDA* and source of data, interviews (i) and meetings (m)

Lean Principle	**Dimensions of analysis**	**Research sub-questions**	**Results**
Value	Identify *Value* from designers perspective	*What do designers' Value in design across disciplines?*	
	Studies I and II (i)		Categories of *Value* for designers
	Identify how designers deliver *Value* in action	*How do designers deliver value to the design process and design results in design meetings?*	
	Study VII (m)		Priority issues in instances of *Value* judgment
	Study V (i)		Categories of drivers of *Priority Value* in decision-making
Value Stream	Identify characteristics of designers' approach	*Do designers sharing the same design environment show the same design approach characteristics?*	
	Study IV (i)		Categories of designers' approach
	Mapping *MUDA* in design	*How to map MUDA in design across different design disciplines?*	
	Study VII (m)		Mapping of instances of *Value* judgment of *Priority Issues*
	Study VIII (i)		Described in Chapter 6, 6.2.
Flow	Identify *Flow* circumstances	*What are designers' Flow stops, breaks and conditions?*	
	Study IV (i)		Characteristics of *Flow* breaks and conditions
	Identify *Flow* interaction sequences	*How do designers deliver Value to the design process and design results in design meetings?*	
	Study VI (m)		Flow diagram of interaction in meetings

<table>
<tr><td rowspan="4">Flow and Pull</td><td>What do designers Value and prioritize in decision-making</td><td colspan="2">Which invariant characteristics across different design disciplines can be found in decision-making?</td></tr>
<tr><td colspan="2">Study V (i)</td><td>Categories of drivers of Priority Value in decision-making</td></tr>
<tr><td>Interdependency and Iteration in design</td><td colspan="2">How do instances of Value judgment evolve in design meetings across design disciplines?</td></tr>
<tr><td colspan="2">Study VII (m)</td><td>Categories of Priority issues
Iteration and Interdependency of Priority issues and instances of Value judgment</td></tr>
<tr><td rowspan="5">MUDA</td><td>Identify MUDA in designers discourse</td><td colspan="2">What situations of MUDA can be found in design across disciplines?</td></tr>
<tr><td>Identify MUDA in designers' action</td><td colspan="2">How far situations of MUDA share invariant characteristics across design disciplines?</td></tr>
<tr><td colspan="2">Study VIII (i)
Study IX (i) and (m)</td><td>Invariant Categories of sources of critical situations and crucial actions in design Meta-level behavior framework</td></tr>
<tr><td>Identify MUDA and coping mechanisms</td><td colspan="2">How do managers with design and non-design background working in the design environment cope with situations of the current crisis?</td></tr>
<tr><td colspan="2">Study III (i)</td><td>Influences and consequences
Elements of coping mechanisms
Actions to activate coping mechanisms
Development of a culture of awareness</td></tr>
<tr><td rowspan="2">LP and MUDA</td><td>Identify crucial actions to cope with critical situations</td><td colspan="2">How do designers prioritize value in crucial actions to cope with critical situations in design across design disciplines?</td></tr>
<tr><td colspan="2">Study X (m)</td><td>Lean Principles as elements of behavior in design</td></tr>
</table>

Results described in Chapter 5 lead to the elaboration of the framework of awareness further explained and illustrated in Chapter 6, which integrates the developed categorization systems and interaction procedures.

Chapter 6 presents the discussion of the main proposals of the present doctoral research: translation and definition of Lean Principles in design, *MUDA* in design as critical situations and its inferences and implications. The absence of *MUDA* situations in design models is brought into perspective in support of the need to study, explain and communicate knowledge of the phenomenon. Then, the description and illustration of the Framework of Awareness integrating the main findings from the empirical studies is depicted.

6 Discussion

'As it happens, most of the problems that most people face most of the time in everyday life are ill-defined problems in these terms. Not surprisingly, in the course of evolution, human beings have found quite effective ways of dealing with them. It is these ways of behaving, deeply rooted in human nature, that lie behind design methods.'

Bruce Archer, 1979. *Design as a Discipline.* p. 17

Design constitutes human being' (Krippendorf, 2006, p. 74). This thesis supports the notion that Lean Principles have an intrinsic and instrumental role in designers' effective and creative behavior. This claim is based on the importance of taking effective behavioral choices in all the stages of design and product development processes, including the creative ones, as having ideas and being able to implement them asks for competent action. Although exploration and exploitation processes are considered opposites in management science (Smulders, 2006), and the importance of effectiveness in creative stages is usually refused, this research gives relevance to the fact that effective behavioral choices are just important to production or organizational processes as to creative stages. This thesis speculates, and asks for corroboration of the intertwined links of mental and physical actions performed to give answers to tasks, such as problem definition, solution and its materialization, and tasks to assure production and management. Such intertwined links might have critical and crucial aspects that influence and suffer influence from actions of *interdependency, planning, framing, information assessment* and *transfer, envision* and *dosage* (Table 5.26) of quality and quantity towards the design completion.

The present doctoral research initially aimed for a threefold contribution to which an explanation is provided:

- First, defines the Lean Principles in design and product development as elements of designers' behavior. However, this claim needs further research, initiated with Study X, to be supported.
- Second, a twist in the understanding of the Lean Principle of *Value* in design leads to the translation of *MUDA* in design as *critical situations.* The claim for an explanatory framework of the translation of Lean Principles and *MUDA* is structured into the *Framework of Awareness* to *critical situations* and integrating the translations of Lean Principles as elements of *crucial actions* in design.
- Third, findings contribute to the knowledge about designers across disciplines and might improve behavior through the application of the framework.

This chapter describes the evaluation and interpretation of results with respect to the original research question drawing inferences and implications. In the following sub-chapters, the present doctoral research proposes the definitions for the translations of Lean Principles and *MUDA* as *critical situations* in design and outlines its relevance to design research. Finally, the *Framework of Awareness to critical situations* derived from the integration of the categorization systems is described.

6.1 Defining Lean Principles in Design

> *"Of course, life's programs are not as linear as this strategy, in the simplified form in which we have presented it. A good strategy would have to contain many checkpoints for evaluation of progress, many feedback loops, many branches, many iterations."*
>
> Herbert Simon, 1971. *Human Problem Solving: The state of the theory in 1970*, p. 145

Taking the Lean Thinking perspective allowed the opportunity to see more in depth and on a transdisciplinary base, how designers cradle and prioritize *Value,* the phenomena of *MUDA* as *critical situations*, its consequences and *crucial actions.* Results show that in this research the *Value* concept differs from the manufacturing to the design contexts and the *MUDA* concept follows the original meaning, but also has positive outcomes. An inference can be made: design needs *MUDA*, as it activates iteration processes of fine-tuning, reviewing and searching for matching solutions. Although iteration is not an exclusive characteristics of critical *Priority Issues* its instances of *Value* judgment fine-tune *Value* definition of the final design. *Value Stream* is translated as design approach, while *Pull* elements in design set its path and course of actions. A *Flow* chart function for mapping *critical situations* in design, comparable to the mapping tools of the Lean Principle of *Value Stream,* is proposed in 6.2, and complements the translation of *Value Stream* in design. Elements of *Flow* in design also assert the path of the design approach, channel, prioritize and support *Value* judgment and also determine iteration and interdependency of *Priority Issues.* The recognition of challenges (*Pull* element) in *crucial actions* enables *Flow* allowing *Pull* to be successful. Some *Priority Issues* are critical others simply have to wait to be solved. For example, the question *what's missing*? works for *Pulling Priority Issues* but does not have a resolute role for critical *Priority Issues.* To Dorner (1996), *'The critical variables in a system are those that interact mutually with a large number of other variables in the system. They are, then, the key variables: if we alter them, we exert a major influence on the status of a system.'*

The present research extends the translation of the Lean Principles and *MUDA* in design, and proposes the concept of *crucial actions,* as mechanisms to cope with *critical situations* which elements are comparable to the Lean Principles. Such elements are: the identification of the challenge (element of *Pull*) underlying the *critical situation* (*MUDA*), the driver towards decision-making (element of *Flow*), and the action (*Value stream*) as necessary coping conditions. Table 6.1 illustrates the translation of the five Lean Principles into design and product development.

Table 6.1. Lean Principles definition in design (this thesis)

Lean Principles		Definitions
Value	Design	*Priority Value*
Value stream	Design	Action that emerge from the process of identifying *Priority Value* and the drivers for decision
Flow	Design	Drivers of *Priority Value* towards decision-making to assure design process continuity or change of direction
Pull	Design	Identification or recognition of challenges or requests with an activation and iteration function
Perfection	Design	Taking *crucial actions*

Lean principles translated in design became elements of innate human behavior. Therefore, and according to the results and observations derived from the empirical studies, this research proposes Lean Principles as elements of behavior in *crucial actions* to cope with *critical situations* in design. This knowledge contributes to a better understanding of what constitutes the designers' *frames* and *moves* (Schön, 1983) and its conscious application might improve performance with such actions.

6.2 *MUDA* in Design as Critical Situations

As the translation of *MUDA* in design was progressing, literature review took place in moments that could influence the research orientation. Drawing from the literature, design and product development research has paid little attention to such design management issues on an empirical basis. The traditional prescriptive models such as the Basic Design Cycle (Roozenburg and Eekels 1995) but also newer approaches such as the VIP approach (Hekkert and van Dijk 2001, 2011), among other design approaches (Lauche, 2007), product development structured methods (Cooper, 2008; Ulrich and Eppinger, 2011), and reflective models of the design practice (Schön, 1983) do not represent the sources of less successful moves, possible effects of *critical situations* that designers and developers have to cope with, individually or in team, in addition to guidelines to improve performance. Similar issues have been addressed as *critical decisions* in risk and uncertainty management approaches to design and product development (Krishnan and Ulrich, 2001; Richtnér and Åhlström, 2006; Jerrard and Barnes, 2006; Oehmen and Seering, 2011; Unger and Eppinger, 2011) and risk management in Lean Product Development (Oehmen and Rebentisch, 2010).

In design research, similar circumstances have been differently tackled. Research attempts investigate problematic situations in studies limited to one design discipline. About forty years ago, Christopher Jones drew a list of five criteria for design project control from a long list of observations mentioned in his seminal book, *Design Methods* (1970). The first of the five criteria is the identification and review of *critical decisions*. Other related attempts were made, namely, the concept of *critical design moves* (Goldschmidt, 1996), derived from a study made with teams of Product design engineers, and the method of *critical situations* (Frankenberger and Badke-Schaub, 1998), derived from empirical studies in the Engineering design practice that depicts mechanisms that lead to success or failure in different types of *critical situations*. Such attempts elaborate on concepts and empirical studies developed for specific purposes, such as design methods, mapping of design cognition, reducing routine tasks and documentation processes (Table 6.2).

Table 6.2. Critical decisions, moves and critical situations in design and product development research

Type and source	**Definition**
Critical decisions in design methods **(Jones, 1970)**	*'Every decision which carries a high penalty must be identified as early as possible. Such decisions should be taken only tentatively at first and should be reversible if they are later found to conflict with reliable evidence or with informed opinion. Critical decisions include the initial assumptions, the objectives, the choices of models, the choice of strategy and the procedure for changing strategy.' p 57.*
Critical design moves in product design **(Goldschmidt, 1996)**	*'The meaning of 'move' in designing is akin to its meaning in chess: a design move is a step, an act, an operation, which transforms the design situation relative to the state in which it was prior to that move.' p 195.* A binary reply system of 'yes' and 'no' is used to determine linkage or its absence in the context of the design task. Backlinks record the path that led to

	a move's generation, while forelinks bear evidence to its contribution to the production of further moves. *'Link-intensive moves are called Critical Moves (CM), and all the Critical Moves of a sequence together describe its critical path.' p 196.*
Critical situations in engineering design **(Frankenberger and Badke-Schaub, 1998)**	The main purpose of the method is the reduction of the documented design process to phases of routine work and critical situations, *'where the design process takes a new direction on a conceptual or embodiment design level' p. 154.* This research proposes five general categories based on the identification of tasks and collaboration: goal analysis, solution analysis, solution search, and disturbing and conflict management.
The decision perspective in product development **(Krishnan and Ulrich, 2001)**	*"coordinated decision making requires an approach to research that is driven by the intrinsic interdependencies among decisions, rather than being driven by attempts to bridge the extant functional structure of the research community" p.12*
Critical decisions In the Risk-driven Design **(Oehmen and Seering, 2011, Bassler et al., 2011).**	The integration of risk management as an intrinsic part of design processes is proposed in the Risk-driven Design framework. The proposal emphasizes that when the design process is driven by the intention to manage risk, known and unknown uncertainties and their effect on the objectives are identified then decision-making focuses on the most critical uncertainties. The authors argue that if risk management is interpreted as the structured identification and reduction of uncertainty, all product development activities that aim at minimizing uncertainty can be seen as risk treatment measures such as quality management and review processes.
Critical situations in design and product development **(Vieira et al., 2012b)**	*The absence of essential aspects of the design process is identified and prioritized for team discussion delaying decision-making in short and long-term.*
Crucial actions in design and product development **(Vieira, this thesis)**	*The identification of the challenges to overcome the source of a critical situation is made based on individual or team Value judgment and converges to the identification of Priority Value(s), and drivers for decision-making constituting actions to be taken in short and long-term for an effective result.*

The data analysis of this research, brought into evidence that the term *critical situation* encompasses four elements of potential critical focus, namely: *the critical Priority Issue,* for example, an advanced idea solution which materialization is not known, difficult or unsure; the *critical circumstance*, in which the *Priority Issue* can be solved but is dependent, for example, from outsourcing or someone's expertise to whom critical aspects might emerge; the *critical decision*, in situations where, for example, the *Priority Issue* is solvable with a better but more expensive solution and decision on the critical aspect of *Value* loss or opportunity is requested; the *critical frame and move*, adopted from (Schön, 1983), in situations where the designer takes a mind frame and moves in actions of critical consequences as less effective results.

The data analysis also brought into evidence the complexity of links between *Priority Issues* and decisions. Managing interdependencies among fundamental decisions made by intention or default (Krishnan, Ulrich, 2001) has been asserted as major importance in design and product development as a deliberate process involving hundreds of decisions that can be supported by knowledge and tools, with implications to risk management (Oehmen and Seering, 2011, Bassler et al., 2011). A call for a more humanistic approach to risk in the area of new product development emerged in the last decade. Such approach requires a deeper understanding of design cultures and an ability to challenge individuals' embedded perceptions of risk (Jerrard et al., 2008). This research brought some evidence of the underlying presence of risk, as *Value* loss and opportunity, and its downside and upside effects in *critical situations* as wastes that are not always wasting, but creative actions to propel *Value.* This thesis draws the following speculations: how far the sources of *critical situations* asserted in this research, which are mental and physical actions, can also be found in the solving-problem processes of *Priority Issues* free of critical focus, and if risk underlines both and how, and if so, what are the similarities and differences; *Critical situations* might not be the unique circumstances for the translation of *MUDA* in design; transforming waste in essentials is one of the characteristics of design, comparable to the hip expression *Cradle to Cradle* (McDonough and Braungart, 2002), that makes designers Lean Thinking enablers.

Representation of the analysis: mapping the awareness

The translation of *Value Stream* as design approach allowed the identification of several characteristics therefore contributes to the knowledge about designers. In addition, *Value Stream* has another aspect of mapping *MUDA*. Knowing the incidence of *critical situations* and *crucial actions* per category was not sufficient to understand the influence and coping mechanisms of *crucial actions* (Vieira et al., 2012b). This thesis proposes a *Flow* chart and asks how far it is useful to design practice and research mapping the awareness of *critical situations* and *crucial actions*. From the analysis of the statements, it was possible to infer four patterns of sequence. The representation of these patterns was done through the creation of an axial *Flow* chart that shows the multidimensionality of the variables that constitute the categories of challenges (Table 5.29). As the 16 challenges are dependent on designers' critical or crucial behavioural choices, the challenges have a variability characteristic. The chart derives from a function created in Wolfram Mathematica software for the representation of the data analysis. This chart considers the 16 categories of challenges in two axial dimensions with a cycle graph that illustrates in four quadrants patterns of sequence in *critical situations* (Figure 6.1). The upper right hand quadrant shows situations where immediate *crucial actions* are perceived and taken. The upper left hand quadrant shows situations where the *crucial actions* were not taken, are insufficient or excessive. The lower left hand quadrant shows the consequent *critical situations.* The lower right hand quadrant shows situations where *crucial actions* can still be taken to cope with the circumstances. As an example, the following image illustrates the sequences that derived from *critical situations* related to the category of *Information transfer*, second level category of *Documentation*. In the following examples are given to each of the four patterns of sequence:

Critical situations that are immediately perceived and the *crucial action* is known have direct solution. In the upper right hand quadrant *Communication* is a *crucial action* to cope with a *critical situation* of *Documentation*. *Documentation* is a *crucial action* to cope with *critical situations* that relate to *Knowledge, Orientation* and *Open-up solutions*. An example is given. (Sequence A, Figure 6.1),

> *'I guess ideas always evolve very, very quickly. I know I have to write down(Doc) what I think because I might already have discarded it in my head. As soon as I think of something, and before I start to think weather it's possible or not possible I write it down, because somehow, when continue to think a bit I might eventually fall back to an idea that in the beginning seemed not possible at all (Opn).'*

Critical situations without a successful resolution lead to other *critical situations*. The up left hand quadrant shows what was not done, overload or absent, (sequence B).

> *'Other thing that can happen is you haven't done enough research about what other people have done (Doc) and you redo the work and then when you try to publish you become to know (Com) - ok, this guy did the same thing five years ago (Sur).'*

Crucial actions that are not taken might lead to unsolvable *critical situations*. The lower left hand quadrant illustrates *crucial actions* of *Documentation* that were not taken, were insufficient or excessive and led to *critical situations* of *Intransparency*, *Surprise*, *Communication and Focus*, for which an example is given, (sequence C).

> *'The whole continuously writing down what I'm doing (Doc) because I have to report everything that I've done and not just showed the product that I have designed, that stops my flow, breaks it, interrupts it and if I could just design only a product, just do that, and maybe sometimes give a presentation to a client or something, as long as it's just designing a problem, it's ok, but there are other distractions (Intp).'*

Crucial actions that do not take place, are excessive or insufficient lead to *critical situations*, that can be solved with *crucial actions*. In the lower right hand quadrant *Adequacy* and *Orientation* are *crucial actions* to cope with these sequences (sequence D).

> *'And of course, there are other parts of the work, like documentation, manuals, that for me is, documentation is important, but we don't make it, we don't have the time for it (Doc). When we finish this project, the next one is already started, our clients do not understand that, everybody thinks in making stuff and not in documenting stuff (Com). We build the system around, the documentation is generated on the fly for the most part, usually in the middle of the project there are the manuals, we expect people to understand how to use what we make, and if they don't we will say how (Ori).'*

The axial *Flow* chart developed as plot tool software, has the utility of mapping *critical situations* providing reflection upon usual behavior and *crucial actions*.

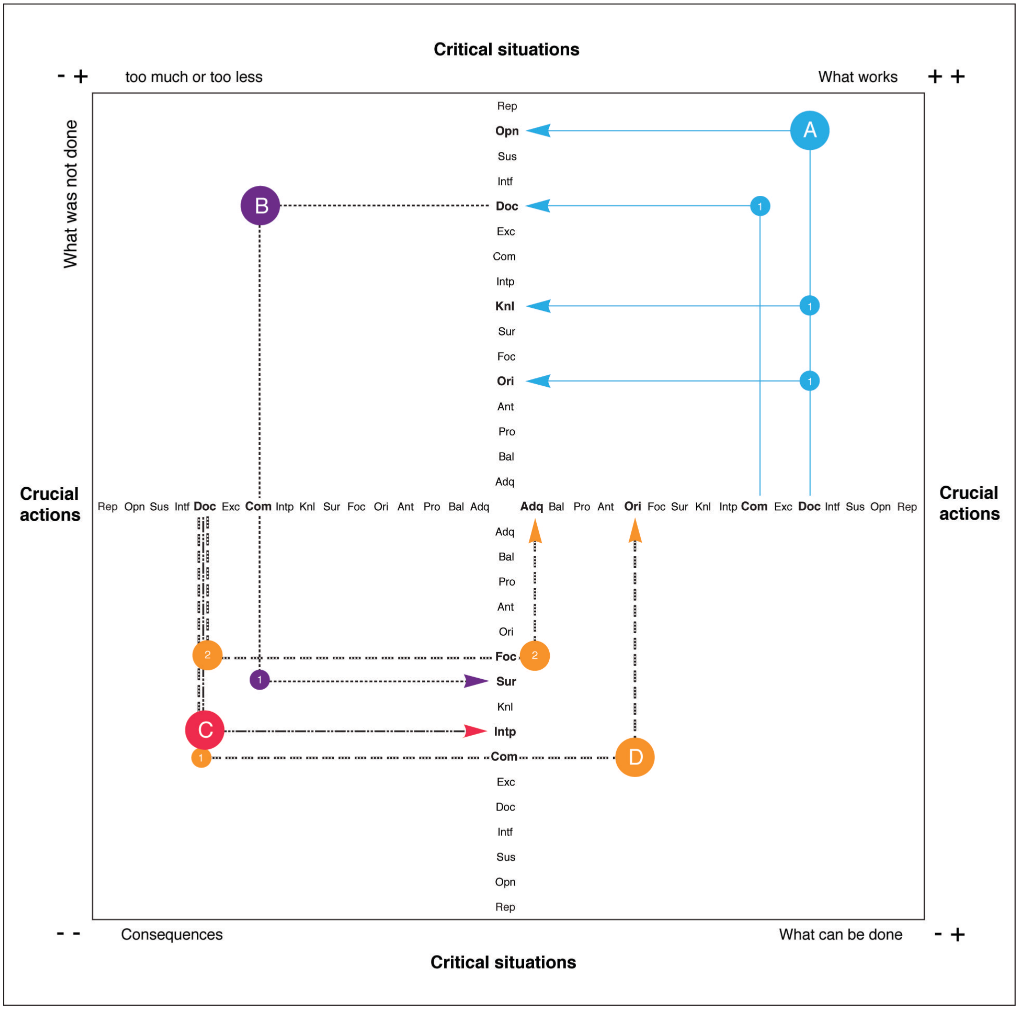


Figure 6.1. Axial *Flow* chart illustrating the multidimensionality of the variables as behavioral challenges in critical situations and crucial actions in design. The chart refers to the representation of situations from the sub-category of challenge, *Documentation*. Acronyms of each variable: Adequacy (Add), Balance (Bal), Probability (Pro), Anticipation (Ant), Orientation (Ori), Focus (Foc), Surprise (Sur), Knowing (Knw), Transparency (Trans), Communication (Com), Exchange (Exc), Documentation (Doc), Interfaces (Intf), Suspension (Sus), Open up solutions (Opn), Representation (Rep).

6.3 Framework of Awareness to Critical Situations

'Adaptation may be quite unconscious and unintended, as in Darwinian evolution, or it may contain large components of conscious intention, as in much human learning and problem-solving.'

Herbert Simon, 1990. *Invariants of Human Behavior*, p. 2

In the past, design awareness was described as '*the ability to understand and handle those ideas which are expressed through the medium of doing and making*' (Archer, 1979, p 20). Nowadays, design awareness has become a relevant design aptitude in the context of complex and collaborative processes of design and product development. The complexity of design asks for conscious intentions to support its practice. The present thesis proposes a *Framework of Awareness* (Figure 6.2 and 6.3) that intends a twofold contribution:

- Support designers' and developers identifying and reflecting on the sources of critical situations, challenges and drivers for crucial actions to uphold and increase performance towards decision-making.
- Integrate the findings from the investigation of Lean Principles and *MUDA* in design with an explanatory framework illustrating the influencing factors of crucial actions to cope with critical situations.

Explanation is given to the *Framework of Awareness* content (Figure 6.2) integrating the categorization systems developed in Chapter 5.

Categories of *Priority Issues*, illustrated in 5.1.4, relate to the design problem *situation*, *strategy*, *measuring*, *validation* or *exchange* activities. *Priority Issues* under *critical situations* follow the paths asserted by designers' *priority*, *emergency* and are many times *unnoticed*. The three paths can lead to iteration of *Priority Issues* and *Value* judgment reducing uncertainty and ambiguity towards decision stages.

Categories of individual *Value*, illustrated in 5.1.1, relate to designers need to have incentives and stimuli. Three main categories of *actions*, *Value(s)* and *application results*, unfold in sub-categories of *motivations*, *inspirations*, *aspirations*, *heuristics*, *gaining knowledge*, *learning*, *collaboration*, *anticipation*, *application results* and *explicit Value(s)*. Examples of codes based on interviewees quotes are given: *answer to the purpose*, *leave a mark and social intervention*, *cope with unexpected situations*, *break paradigms*, *keep external look*, *adopt an experimental approach*, *have access to information*, *clarify doubts*, *have a notion of the territory and own position*, and *achieve change* in the application results and *sustainability*.

Categories of team *Value*, for the design approach illustrated in 5.1.2, relate to the main categories of *environment*, *team*, *designer*, *management*, *process* and *performance*. Examples of codes stated by the designers are: the *need to have a good working environment*, *communication Flow*, *understand each other's perspectives on the design problems*, *managing resources*, *finding strategies*, and *individual and team performance*.

Categories of design-subject *Value*, illustrated in 5.1.3, are *emotion-based*, *intuitive-based*, *rational-based*, *experience-based and constraint-based* and consist of drivers for *Priority Value* in decision-making. Priority for evaluations is given based on inputs such as, *the sensations to transmit to people*, *feeling certainty about a choice without argument*, *characteristics of the design problem context*, *users experience*, and *time*, *client or cultural conditions*.

From evidence of the designers awareness to the influence of external inputs and needs in Studies VI and VII, a deductive categorization system entails four categories for decision-making: *Political-based*, *Business-based*, *Competence-based and Preference-based*. Examples are, a *political choice from the client*, a *business collaboration* that is included in the project, a choice based on *competence of the outsourcing services*, or based on the *preference for a certain style of approach* that seems to be adequate to the design goal.

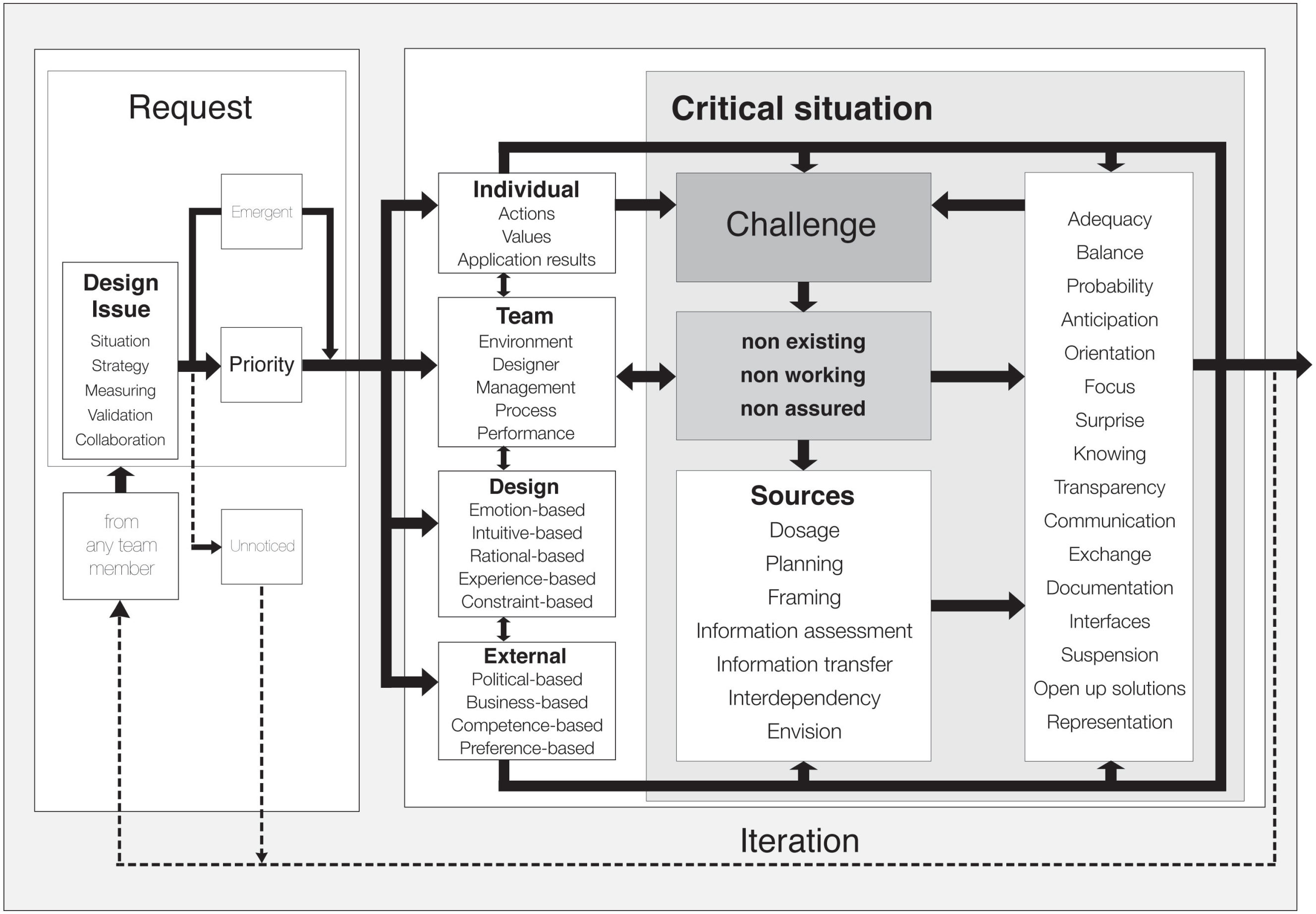


Figure 6.2. Content of the Framework of Awareness: categorization systems. Priority Issues *(Pull)*, its four sources of claim, Value for designers, *(Value)*, Design approach *(Value Stream)*, Drivers for decision-making *(Flow)*, Critical situations sources *(MUDA)* and challenges.

The categorization systems support the discussion, *Value* judgment and decision-making of *Priority Issues.* The categories illustrated in 5.1.5, support the identification of sources of *critical situations* and *challenges* that constitute alternate combinations with criteria from the described categorization systems, activating elements of *crucial actions* to solve the *Priority Issues* under *critical situation.*

An explanation is given of the *Framework of Awareness* process (Figure 6.3). The framework supports the activation of the individual, team, design and external actions holding *Value* input to cope with *Priority Issues* under *critical situations* as an adaptive set of principles to apply in any design process model. Three stages are relevant to the *Framework of Awareness:*

- **Input -** There is an input situation to discuss a *Priority Issue* that starts with a request for update or based on a doubt about an essential feature.
- **Instance of valuation -** There is an instance of valuation that from the analysis of the request evolves to a point where one of the team collaborators challenges the team based on the identification of *non-existing, non-assured* or *non-working* essential features. The discussion involving all the present collaborators is focused on the identified challenge and each designer argues his/her point of view based on the set of *Value(s)* inherent to his/her own activity. The identification of the source of the *critical situation* is spontaneous or based on the proposed categorization system (chapter 5.1.5), which can help keeping track and mapping the sources and paths of *critical situations.* A categorization of challenges defies designers to figure out what can be done or which *long-term crucial actions* should be taken if there is no immediate resolution.
- **Output -** There is an output situation where an individual or team-based decision is made. Two things can happen, a decision based on the agreement of a *crucial action* to be taken, or a postponed decision based on interdependencies with other *Priority Issues,* under uncertainty that leads to an iteration process.

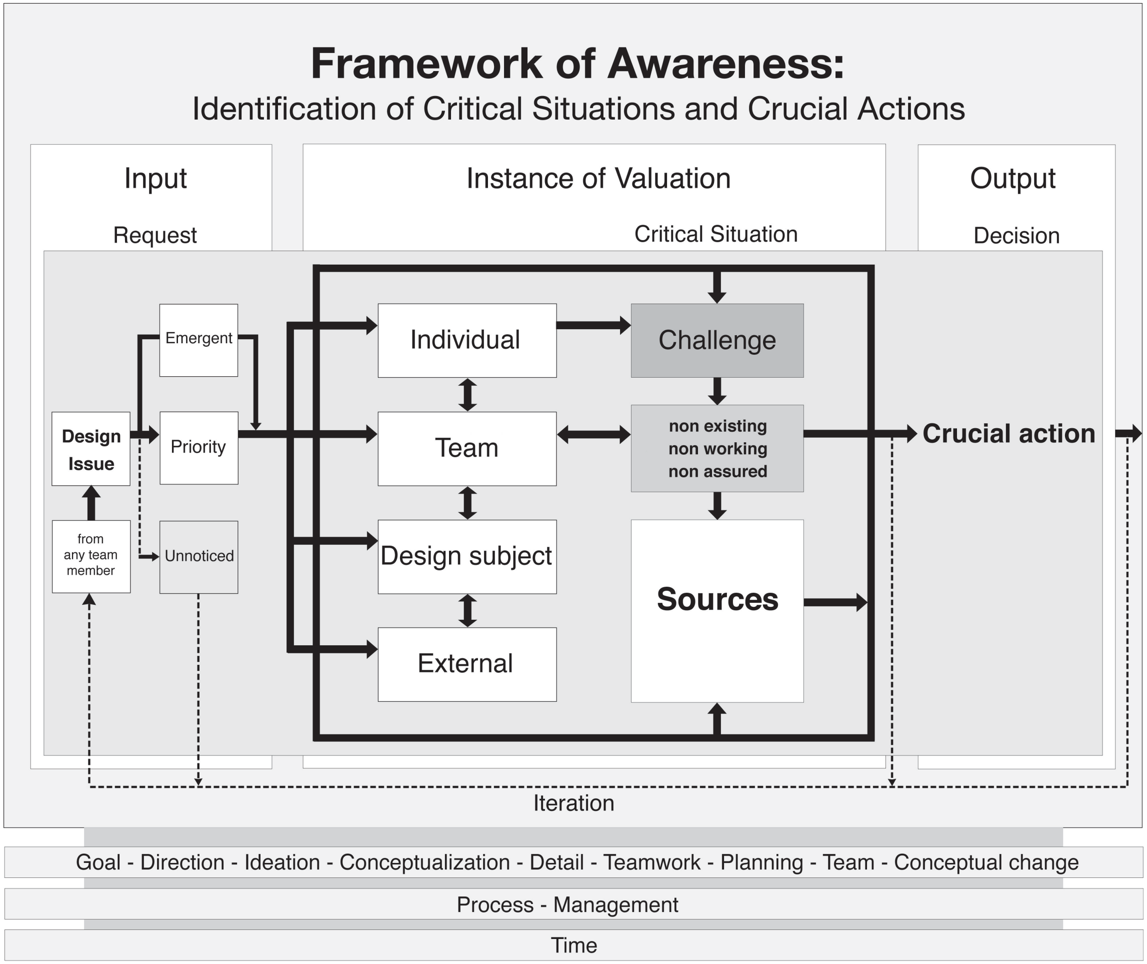


Figure 6.3. Process of the Framework of Awareness integrating the categorization systems in the sources of claims for critical situations, as elements of crucial actions to cope with design issues, set with priority or emergency for discussion and revealing iteration processes.

Hypothetical case descriptions are given with three examples. The absence of a colleague without whom the design cannot advance (*Priority Issue*, of *collaboration*) becomes a team *Value*, that is *not assured*, and has the *critical* aspect, which source is *interdependency*, that can have a negative outcome in case, for example, a deadline cannot be postponed, or challenge the team to accept *suspension* leading the design development to iteration processes towards resolution. The specific characteristics of a space for setting an exhibition (*Priority Issue* of *situation*) determine design *constraints* that do not allow bringing the initially proposed constructive methods indoors. Such *technological-constraints* drive decision on which materials and construction methods can be handled inside the space *(challenge: adequacy)*, and sets a critical aspect which source is *Framing* that influence the global design of the exhibition *(Priority Issue,* of *strategy)*. Negative consequences would happen if for example *time-constraints* do not allow rethinking the supporting structure for the same global design, or positive consequences if recognizing opportunities to improve the global and partial design solutions would reframe the design approach *(challenge: orientation)* and facilitate the construction. As final example, the designers' *preference* for the style of a professional photographer *(Priority Value)* is rejected *(challenge: suspension and possible Value loss)* as the client outsources the services to another person setting a critical aspect *(challenge: adequacy)* of possible inadequacy.

Almost one century after the first known design research attempts (compiled in Pahl et al., 2007), it is still pertinent to understand, externalize and improve the effectiveness of the design process (Cross 1984, 2007). The main reason of concern with more methodical and conscious approaches to design relates to the need to tackle many uncertainties and complexity inherent to design tasks with structured but also procedural flexibility. Intuition still remains an important aspect that persists as an argument against the adoption of systematic design procedures (Alexander, 1964). Although economic theory assumes that people make their decisions to maximize their utility (Simon 1979), the assumption that people are always rational and internally consistent in their allocation of choices was found to be not always true (Kahneman and Tversky, 2000). However, the notion that choices are taken for the purpose of maximizing expected or anticipated utility remains a central assumption to neuroeconomists and designers and managers to whom intuition plays a relevant role (Simon, 1987; Dane and Michael, 2007). Design problems are possibly undetermined (Dorst, 2005), to which expected or anticipated solutions and outcomes must be found.

It is acknowledged that a widened and integrated approach to design would be one in which rigidity and flexibility are properly balanced (Jones, 1970), and for a general working methodology to be widely applicable, it must be independent of discipline and should not require specific technical knowledge from the user, but support a structured and effective thinking process (Pahl et al., 2007). This thesis speculates that a principle-based approach would still remain systematic but also a flexible approach to design. The proposed translation of the Lean Thinking set of concepts in design, summarized in the *Framework of Awareness* presented in this doctoral research, is widely applicable across design disciplines, does not require specific technical knowledge, aims to support an effective thinking process, and balances rigidity and flexibility with a set of principles-based, of non-linear but cyclical and momentarily application to any situation of non-spontaneous resolution, inviting designers and developers conscious and intuitive approach to take the best from the recognition of opportunities.

The added *Value* of the present framework is the relevance given to the opportunity of managing the influence of *critical situations* and interdependency between *Priority Issues* with alternate behavioral choices based on organized criteria with free application at any time along the design process. In addition, the framework supports designers with empirically derived knowledge on adaptive behavior to improve performance toward decision-making. The *Framework of Awareness* challenges designers and developers to reflect upon their behavior and effective performance in situations that ask for management aptitude. This doctoral thesis proposes a principle-based and domain-independent approach that can help designers identify sources of *critical situations* and the elements of *crucial actions* that can influence decision-making and the trajectory of the design process.

Chapter 7 concludes the present doctoral research with the knowledge contributions of the thesis, implications to design management, practice and education, research limitations and further research.

7 Conclusion

'*In the middle of difficulty lies opportunity*' (Albert Einstein) is the suggestion of the present framework. *Critical situations* entail difficulties to which opportunities of resolution must be found. Moderating this basic tenet is the phenomenon that creativity can be enhanced under conditions of optimal frustration, as well as under conditions of difficult but achievable challenge (Boland and Collopy, 2004). Creative processes are essential to innovation (Buijs, 2012) and context, motivation, time and pressure play essential roles in framing design problems (Root-Bernstein et al., 2003) leading to different levels of creativity (Taylor, 1959). In such circumstances, designers' mind-set and approach have different expectations and orientations facing opportunity for intervention and questioning some basic assumptions.

7.1 Knowledge Contribution of the Thesis

This research widens the scope of the Lean Thinking philosophy, translating the Lean Principles and *MUDA* to design and product development, opening ways for a the understanding of a research gap of the Lean Principles role in any stage of the design process including the creative stage, so rich in *critical situations.* Findings aim to enhance the knowledge about designers' and improve behavior and performance supporting designers' need to "*observe their own thinking in a objective way*" (Jones, 1970, p. xii), for an effective *Value* definition in the design process. The thesis extends the notion of performance to a broader meaning, not product performance but people performance with procedures that can be quantified, not just quantitatively but also qualitatively. This framework does not represent a checklist, but proposes its application in the design practice to nurture a culture of awareness. The research, first explores the analytical principles adopted from the Lean Thinking and the dimensions of analysis (Table 2.3) to reach the synthetic principles and integrate the set into a framework.

The present doctoral research proposes a *Framework of Awareness* derived from empirical studies and inferred from the integration of results, based on the developed categorization systems and interaction modus operandi. Five categorization systems with influence in designers' approach and decision-making in design are proposed as invariants of designers' thinking and acting. The research argues that design integrates invariant categories of *Value*, design approach, drivers of *Priority Value* and *Priority Issues* for decision-making across design disciplines. These categorization systems may help to establish supports to a better understanding of language in inter, multi and transdisciplinary design environments across disciplines. The empirical evidence of such characteristics contributes to transdisciplinary knowledge on elements of decision-making in design with application in design practice and education. Design practice, management, and education in the areas of design and product development field can benefit from the present contribution.

In addition, a relevant consequence of this research is the assessment of similarities and differences across design disciplines. The notion of a generic design (Goel and Pirolli, 1989) led to the major attempt of (Goel and Pirolli, 1992) generic design hypothesis regarding the study of design as a subject matter in its own right. The studies presents findings of commonalities in the structure of design problems and tasks across some design disciplines, as well as, of significant differences in the structure of design and non-design problems (Goel, 1994), and represents a contribution to structuring the design core knowledge domain. Other paired studies were asserted through empirical research (Visser, 2009; Akin, 2001; Cross, 2006) on diverse design domain concerns. A second attempt is the cognitively oriented generic design hypothesis (Visser, 2009) that exhaustively identifies contributions to structure the notion of a body of knowledge of a generic design. These concerns derive from the following assumptions: a) different design disciplines share major commonalities; b) different design disciplines show variation in similarities; c) designers approaches vary across design disciplines; and d) design situations frame design approaches creating variance in designers cognition. Although significant attempts have been made, the later generic-design hypothesis claims for augmented empirical evidence and validation of commonalities and differences across design disciplines. Findings derived from this research attempt to contribute to the generic-design hypothesis with evidence of invariants in design across disciplines. The extent to which the doctoral thesis answers to the main research question is described,

> *How can Lean principles contribute to the knowledge of the design process and designers behavior across different design disciplines?*

The progression of findings and the understanding of the different case studies, cultures, design philosophies, specific methods, tools and sequence of practices led to understand that design across disciplines has different levels of influence. Characteristics are widely shared among designers and non-designers and invariants are achievable on an abstract and qualitative level.

As concluded in the end of Chapter 5, the research sub-questions were partially answered. The thesis was exploratory and experimental in nature, once it was based on untested ideas, methods and experience. Therefore, validation and reliability were not considered objectives to completely fulfill. The main contribution of the thesis is the translation of the Lean Principles and *MUDA* in design, creating streams to further design research. Results from the several studies showed evidence of the characteristics illustrated in Table 7.1, and therefore contribute to the knowledge of the design process and designers behavior across different design disciplines. Table 5.33 summarizes the results from the empirical studies, Table 7.1 presents additional findings inferred from the interpretation and integration of results of the present doctoral research.

Table 7.1. Answers to the research question and sub-research questions

Lean Principle	Dimensions of analysis	Research sub-questions	Results
Value	Identify *Value* from designers perspective	*What do designers' Value in design across disciplines?*	
	Studies I and II		Categories of *Value* for designers
	Identify how designers deliver *Value* in action	*How do designers deliver value to the design process and design results in design meetings?*	
	Study VII Study V		Priority issues and instances of *Value* judgment Categories of priority Value in decision-making
Value Stream	Characteristics of designers' approach	*Do designers sharing the same design environment show the same design approach characteristics?*	
	Study IV		Categories of designers' approach characteristics
	Mapping MUDA in design	*How to map MUDA in design across different design disciplines?*	
	Study VII		Mapping of instances of *Value* judgment of priority issues
	Study VIII		Axial *Flow* chart of the multidimensionality of the variables
Flow	Identify *Flow* circumstances	*What are designers' Flow stops, breaks and conditions?*	
	Study IV		Characteristics of *Flow* breaks and conditions
	Identify *Flow* interaction sequences	*How do designers deliver value to the design process and design results in design meetings?*	
	Study VI		*Flow* diagram of interaction in design meetings with stakeholders
Flow and Pull	What do designers *Value* and prioritize in decision-making	*Which invariant characteristics across different design disciplines can be found in decision-making?*	
	Study V		Categories of priority *Value* in decision-making

<table>
<tr><td rowspan="2"></td><td>Interdependency and Iteration in design</td><td colspan="2">How do instances of Value judgment evolve in design meetings across design disciplines?</td></tr>
<tr><td colspan="2">Study VII</td><td>Categories of Priority issues Iteration and Interdependency of Priority issues in instances of Value judgment</td></tr>
<tr><td rowspan="6">MUDA</td><td>Identify MUDA in designers discourse</td><td colspan="2">What situations of MUDA can be found in design across disciplines?</td></tr>
<tr><td colspan="2">Studies I, II</td><td>1st translation of MUDA in design</td></tr>
<tr><td>Identify MUDA in designers discourse and action</td><td colspan="2">How far situations of MUDA share invariant characteristics across design disciplines?</td></tr>
<tr><td colspan="2">Studies VIII and IX</td><td>MUDA in design as critical situations
Invariant Categories of sources of critical situations and crucial actions in design
Meta-level behavior framework</td></tr>
<tr><td>Identify MUDA sources and coping mechanisms</td><td colspan="2">How do managers with design and non-design background working in the design environment cope with situations of the current crisis?</td></tr>
<tr><td colspan="2">Study III</td><td>Influences, wicked measures and consequences
Elements of mechanisms to cope with situations of crisis, development of a culture of awareness</td></tr>
<tr><td rowspan="5">LP and MUDA</td><td>How do designers seize crucial actions to cope with critical situations</td><td colspan="2">How do designers prioritize value in crucial actions to cope with critical situations in design across design disciplines?</td></tr>
<tr><td colspan="2">Study X</td><td>Lean Principles as elements of behavior in design</td></tr>
<tr><td colspan="3">Elements of Crucial Actions in design</td></tr>
<tr><td colspan="3">Definition of Lean Principles in design</td></tr>
<tr><td colspan="3">Framework of Awareness to Critical Situations and Crucial Actions in design</td></tr>
</table>

Designers aim for the implementation of design. Such purpose drives designers to design action in concrete situations. Such activities and situations happen in the social context of design within its multiple and interdependent influence and multidirectional drivers.

7.2 Implications to Design Management and Education

The results derived from the present doctoral research have implications to design management and education aiming to support the design practice, improving designers and developers' performance and facilitate decision-making. The *Framework of Awareness* provides guidelines to support designers' framing their interventions and eventually change previously identified less successful patterns of behavior in design. The framework provides a meta analysis to reflect on thinking and acting and on what prevents designers from changing. The usefulness of the practice of this framework involves an internal review so that each designer can become aware of the degree to which usual performed patterns are consistent with a less successful process and outcome. The framework contributes to designers' professional competence and to professional education assuming that competence is based on the ability to develop theories of what to do in new situations and to behave effectively (Argyris et al., 1985). Examples of designers' actions for intervention or coping with circumstances derived from the case studies relate to *proposing alternative solution*, *setting a strategy*, *searching for other design trajectories*, *reducing discrepancy*, *measuring features*, *searching for a trust source*, *reducing error*, *preparing drawings*, *requesting information*, *balancing costs* and *stating "yes" or "no"*.

The Framework, if adopted by designers and developers, can lead to a mental state that allows reflection on a meta-view of the situation. The practice of this mental but also tangible exercise in *critical situations* of the design practice brings an educational aspect of adaptive behavior that can be absorbed into a more natural behavior with time. Consequently, it can lead to better communication, and a more thorough analysis and awareness to adaptive behavior. The importance of elaborating a *Framework of Awareness* to such circumstances in the business context of design can help managing but also understand the consumption of several types of resources, such as time and creative stability, while upholding performance and persevere with motivation. Adaptive behavior also creates shared understandings of other collaborators' reactions, *Value(s)* and approaches, as well of clients that are usually willing to reflect, discuss and learn from the development of the expected designs.

Francis Bacon phrased the term *"instantia crucis"*, crucial instance, which he explained as a metaphor for a crux marking a crossroad (Novum Organum, 1620). Newton and Boyle took up the same metaphor in *"experimentum crucis"*, crucial experiment, meaning a moment of decision and significance (Romesburg, 2009). This doctoral thesis takes a similar metaphor and proposes the term *"crucial action"* *("cruciallis actio")*, as a moment of decision that asks for valuations of alternative directions and acting that determines a trajectory for the best possible outcome. For Bacon, finding the essence of a thing was a simple process of inductive reasoning and listing all the situations where such essence is or is not found. In the present framework, a categorization system of the sources of *critical situations* leads to the identification of *challenges* in *crucial actions* in design. The meta-level behavior framework (5.1.5) is supported by other categorization systems that contribute to the knowledge of the design process and designers' behavior and performance across different design disciplines. However, the use of the framework is not intended as a checklist, but to help designers developing and nurturing a culture of awareness to the investigated phenomena. Transforming the empirical and theoretical results into a support tool for designers could mean the materialization of the framework into a design tool, for example a game, in the Dutch and Delft tradition, elucidating designers and developers about the use and usefulness and improvement of the framework.

Findings from this thesis can be subject to testing in design education to see how far the proposed efforts improve effective design practices. The research can contribute with knowledge to teaching activities for education in design product development with insight on adaptive behavior in situations of critical influence in design and product development. For example, exemplifying the sources of critical *moves*, phrasing Schön (1983), and challenges in *crucial actions* through a sketching experience. Explaining the framework through the example of sketching could be a way to test its acceptance among students and in design education. Experimenting the framework in education would be a planned initiative, starting from a very basic task such as sketching, where actions related to *dosage, framing* and *envision* take place, and then extending the framework application to other tasks of the design approach and process, including *representation*, creative, strategic and management tasks. Thus, creating attractive ways for the explanation of the framework and assignments including *critical situations* would be means for preparing students to real life design environments. In the projecting age in which we live (Maldonado, 1990), design is considered as a power and fundamental discipline of the 21st century (Bonsieppe, 1992) deserving support to assure its effective implementation.

7.3 Limitations and Further Research

The research proposes the extension of the Lean Thinking philosophy into design, taking its concepts as dimensions to further directions in design research. As expected and felt along the six years of development, the research has its limitations. Although carefully chosen, findings are based on five case studies, which means a lot of data and many research issues to handle by a single researcher. The overload of analysis and challenging integration of findings was a demanding task that asked for many twists and untwists of notions and perspectives. As result of a qualitative research, this thesis presents findings that need to be replicated for possible improvement and validation. Results are not enough for a complete validation of the findings. Results provided a transversal and explanatory framework and it is likely that some of the findings will generalize or be complemented with further studies in other design disciplines. Application, corroboration and confirmation of results ought to be an incentive to other researchers with other case studies. Further developments ought to be accomplished by a team instead of a single researcher.

This dissertation could be considered as an embryonic first book of five, taking the Lean Principles and *MUDA* as dimensions to study designers' behavior. The exploratory research approach, was also experimental as previously mentioned. Therefore, many limitations were found and hindsight brings improvements on research methods, reframed objectives, possible application and usefulness. For example, the Graphic design case study provided many sources of data collection such as emails, projects of very high-resolution level and tight interdependency in decision-making such as book covers and long-term partnerships. However, the data collection across the other cases revealed interviews and the observation of meetings as common data sources. Therefore, further studies based on the analysis of other sources of data might bring additional perspectives to the research.

The broad aim and scope of this doctoral thesis, revealed many streams of research that were just briefly tackled. Such design research issues are briefly proposed as speculations, namely: the connection between question-asking and the elements identified in the translation of the Lean Principle of *Pull* in design; the role of *critical situations,* as decisive situations, crucial to the definition of strategies and conceptual change (Jones, 1970); narrow down the investigation of the link between *critical situations,* risk and uncertainty, although referred to since the first conference paper of this research, a direct connection was not forged understanding possible management implications within Lean Principles; narrow down the focus of further research to more precise and instrumental aspects of design management such as change; understand how the link between *Priority Issues,* iteration and reducing uncertainty in decision-making contributes towards the design completion; the investigation of the interrelations between *critical situations*, the definition of strategies, *crucial actions* and their implications to conceptual change; the analysis of *Priority Issues* that activate anticipation and prevailing strategies, which might bring further insights on designers' thinking and acting for long-term and expected design purposes; further research ought to investigate the interrelationships and patterns of sequence between the sub-categories of the developed categorization systems. In addition, some evidence raised the proposition that the source of *MUDA* varies in the several iterations of the same *Priority Issue.* This thesis speculates that the concept of *crucial actions* can be extended as coping mechanisms of other situations in design, further research might corroborate or not such propositions.

To conclude, the current times of crisis are profuse in *critical situations of potential Value* loss, absence or unsure features and resources, but also opportunities to take *crucial actions*, such as reframing the mind set, design approach, *Value* systems and bring change to design solutions. Design as a process of thought emerges as a way of facing the crisis context with inherent creativity motivated by the chance of intervention and the opportunity to improve people's life quality. Times of crisis influence the acts of design management. On the same root of research issues, such as, emergency management (Alexander, 2002) and risk management (Hubbard, 2009), the topic of crisis management (Mitroff, 2001) came into sight for a systemic view of situations of crisis and its main elements and coping measures. This doctoral research proposes *crucial management* for a systemic view of *critical situations* and support research of coping mechanisms of *crucial actions*. Detection mechanisms such as, *anticipating, sensing, reacting to, containing, learning from,* and *redesigning effective organizational procedures* (Mitroff, 2001) constitute mental and physical actions that nurture awareness in the acts of management and designing to keep up with times of crisis, but also with *critical situations* (Seeger et al., 1998). Sources of *motivation* change, with cost and time *constraints* having a higher impact on design activities and idea generation (Savage et al., 1998, Liikanen et al., 2009), leading to *Value* systems adaptability and change. *Pressure* influence increases concerns with *trust, emotional alignment, knowledge sharing* and *communication* (Pulm and Stetter, 2009) and financial *sustainability* becomes a major issue (Savage et al., 1998). Flexibility increases regarding processes, planning and strategic innovation (Georgsdottir et al., 2003), influencing approaches and courses of action. A superior effort is made to do not affect mood and creativity (Kaufmann, 2003), emotional alignment and intuitive use of tools for innovative thinking (Root-Bernstein and Root-Bernstein, 2003). Creative people always seek for higher challenges. A more convergent effort is made to overcome the challenge of staying in crisis. Times of crisis seem to be appropriate to further investigate Lean Principles and *MUDA* in design.

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Appendices

Appendix A: Half-structured interview

1. Introduction

The interview addresses value and flow in the design process. Attempts have been made to approach value from the perspective of the client and the user. Presently, approaches to value from the perspective of the designer start to take place. What is value for the designer? What do designers consider important during the design process? What do designers consider important but do not communicate because he/she knows that the other intervenient might do not understand?

A second issue of the interview is the question of process flow. What circumstances break flow of work and what aspects provide flow. If you think about examples during the talk, let me know, and please describe it.

2. Groups of Questions

Group I. Main values in designer's role and design discipline

1. What do you think in general designers can/should add in solving a design problem?

1.1 What are in general your values (as designers or other activity)?

2. EN. As a designer/other for what values do you fight?

3. EN. What is that most distinguishes your design discipline from the other design disciplines?

3.1 Can you identify in what way design approach differs in digital design?

3.2 What are the grey areas between your design discipline and other design disciplines?

Group II – Values in motivation

4. What is your motivation in designing?

4.1 What is that you like most in a project?

4.2 What is that makes you feel motivated?

4.3 Is there any project that you particularly had enjoy to do, and why?

4.4 What is most embarrassing for you in a project?

Group III - Values as a professional and as a person

5. What are the main values that most influence your approach to your activity?

5.1 What values are important to you as a professional designer/other?

5.2 What are the most important values to preserve/enhance in this activity?

5.3 In how far is there a difference in you as a professional designer and a person in terms of values?

Group IV – Values regarding clients

6. Through what ways do projects/clients come to you?

6.1 What are your main concerns in answering to the client request?

6.2 How important is to keep your position with the client?

6.3 What kind of tactics and strategies do you use to persuade the clients?

6.4 What main values do you stand for when you have to defend the office?

6.4.1 What are the values to preserve in the relation with the client?

7. Do you accept all kind of projects?

7.1 Which are your criteria in selecting projects?

7.2 Is there other projects that are accepted to unsure the relation with the client?

8. Can you define a project/profile to each one of your collaborators?

8.1 What kind of projects do you deliver to each one of them?

Group V – Values in planning

9. Regarding planning how do you usually proceed?

9.1 Which are the main phases of planning?

9.2 How much time/percentage do you attribute to each phase in planning?

9.3 Do you use specific software for planning?

9.4 Regarding personal resources how do you plan work distribution?

9.5 Which other influencing factors do you consider?

9.6 What number of solutions do you consider for a project?

Group VI – Values in management

10. What conditions do you provide to your collaborators?

10.1 What conditions does the office provides to you?

11. What measures to you undertake to keep the team up to date?

11.1 Do you feel the need for research in the office? Why?

12. How do you define the office quality criteria? What criteria?

13. How do you see the office image reflected in society?

13.1 What are its important aspects? Particular marks?

Group VII – Values in the organizational team

14. What do you do to make your collaborators feel engaged with the team and the projects?

14.1 What is important to feel engagement with the team and the projects?

15. What aspects, values are important to you in teamwork?

15.1 What values stand behind your organizational model?

15.2 What are the advantages and disadvantages of your organizational model?

15.3 What would you change?

Group VIII – Values in management related to project

16. What is important to keep in mind concerning the economical aspects of a project?

16.1 How do you regard economical pressures in projects?

16.2 What are the main difficulties?

16.3 What can be underestimated in calculating a project budget?

17. What kind of emotional attachment to projects do you perceive in yourself/your collaborators?

17.1 How can it be reflected in the final result?

18. What change do you want to make and leave in the projects?

18.1 How would you describe the variation of what is important along the design process, from concept to materialization and launch?

Group IX - Values in the design process

19. EN. What is that you consider being more important, more essential in the design process?

20. What is that you consider as essential in finding a way to proceed?

20.1 Is it important to have things clearly defined in the beginning of a project? Why?

20.2 Do you feel difficulties in starting a project? Why?

20.3 What do you think it is behind, underlying those difficulties?

20.4 In your perspective what essential elements should constitute the briefing?

21. How do you deal with pressures along the design process?

21.1 What influence do you attribute to pressure in the design process, and in the final result?

22. As a designer/other what is most important to you in the conceptualization phase of a project?

22.1 What else is important? What else comes to your mind?

23. How do you come up with design solutions? What is the notion you have about how a design solution changes along the design process?

23.1 In what situations do you think about one concept solution or more than one?

24. What words do you use to identify the image of a project solution? What is most important to you in the characterization of the image of a project solution?

24.1 What are the main aspects you consider when creating an image to a project?

24.2 What do you think when you are working in the project image?

24.3 Do you identify common aspects among projects image?

24.4 Which other aspects complement projects definition?

24.5 What groups of variables/or constants are essential to you?

24.6 What principles of composition do you use?

25. Can you describe your own mental process approaching a design problem?

25.1 Can you identify your particular way of thinking about design?

25.2 Can you identify important point marks/elements during your mental process?

25.3 Does intuition play a role in your approach to designing? What role?

25.4 In which parts or situations of the design process does intuition has more influence?

26. Do you identify an emotional cycle during the design process?

26.1 Can you describe the emotional cycle alongside a design process?

26.2 Do you have the notion of what can be its sequence?

26.3 What emotional aspects are important to you, in your work, along the design process, and in the final result?

Group IX – Values in expertise

27. Do you identify experts in the office?

27.1 Which important lessons have you been learning through all your experience?
27.2 What do you have to say about the relation with the experts?
27.3 Can you identify essential aspects of experts project inputs?
27.4 What is that they always have in mind?
27.5 What are the advantages of working with an expert?

Group X – Flow

Introduction: now we go into the topic of flow. Flow is described as a state of concentration or complete absorption with the activity at hand and the situation.

28. Is it important to have a continuous flow in the design process?

28.1 In what situations do you encounter breaks, stops, in the design process?
28.2 What are the more frequent situations? Why?
28.3 What are the more particular situations? Why?
28.4 How do you deal with that?
28.5 Do you ever feel the need to stop? Why? What do you do in these situations?
28.6 What makes things flow in the design process?
28.7 In what situations do you encounter breaks during the development of a project?
28.8 Do you identify specific flow breaks, stops in your collaborators? In what situations?

Group XI – Other questions

29. Do you have a key sentence, a theory, or a famous thought that guides you in your work?

29.1 Do you want to comment related issues that were not focus until now?
29.2 Is there something else you want to say?

30. Can you give a hierarchy of main values in designing?

Appendix B: Questionnaires

Questionnaire about a categorization system on what designers Value in their activity

This questionnaire is about a categorization system derived from the coding analysis of 10 designers' interviews. The analysis of what designers' value in their activity led to the following categories and codes further illustrated. With this questionnaire we would like to know your perspectives on the categories and weather the criteria makes sense and is meaningful to you. We ask you how far you agree with each statement.

Categories	Criteria	Please indicate to what extent do you agree with the categorization of each of the criteria to each category? Doesn't fit				Fit
		1	2	3	4	5
Motivations	Add design value					
	Answer to the purpose					
	Creation and materialization of ideas					
	Find the way to proceed					
	Search for essentials					
	Stimulating projects					
	Search for your territory					
	To engage the others					
	Listening to experts input					
	Find a solid concept base					
	Observing					
	Keep external look					
	See, feel things matching					
	Is there any criterion missing in the category? Please fill in.					
Aspirations	Create emotional cycles					
	Create novelty					
	Leave a mark					
	Social intervention					
	Break paradigms					
	Is there any criterion missing in the category? Please fill in.					
Inspirations	Unexpected situations					
	Is there any criterion missing in the category? Please fill in.					
Gain Knowledge	Access to information					
	Inform yourself, look around					
	Develop know-how					
	Know the interests of collaborators					
	Know the target group					
	Know the client					
	Is there any criterion missing in the category? Please fill in.					
Learning	Rethink in time and experience					
	Find strategies					
	Negotiating					
	Clarify doubts					
	Planning					
	Review					
	Speak the same language					
	Information organization					

	Notion of territory and own position					
	Is there any criterion missing in the category? Please fill in.					
Prevention	Anticipating					
	Selection of clients and projects					
	Is there any criterion missing in the category? Please fill in.					
Provide structure	Working environment					
	Is there any criterion missing in the category? Please fill in.					
Explicit Values	Cooperation					
	Communication					
	Ethics					
	Economy					
	Coherence					
	Quality					
	Sustainability					
	Innovation					
	Management					
	Control					
	Experimental approach					
	Is there any criterion missing in the category? Please fill in.					
Application results	Change					
	Exchange					
	Compensation					
	Permanence					
	Is there any criterion missing in the category? Please fill in.					

1. Motivations play an important role in designers' activity. Do you think motivations are important enough to be a category of what designers value?

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

2. Aspirations have a relevant role in designers' activity. Do you think aspirations are important enough to be a category of what designers value?

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

3. Inspirations have a crucial role in designers' activity. Do you think inspirations are important enough to be a category of what designers value?

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

4. To gain knowledge about several aspects of a design process is one of the objectives of designers. Do you think gain knowledge is important enough to be a category of what designers value?

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

5. Learning is a fundamental part of the design process and designers advancement. Do you think learning is important enough to be a category of what designers value?

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

6. Prevention has a crucial role in designers' activity. Do you think prevention is important enough to be a category of what designers value?

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

7. Providing and having structure in the working environment it's essential for designers. Do you think providing structure is important enough to be a category of what designers value?

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

8. Explicit values have an important role in designers' activity. Do you think explicit values are important enough to be a category of what designers value?

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

9. Application results during and beyond the design process and final product are relevant for designers. Do you think application results are important enough to be a category of what designers value?

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

10. How far do you agree with the proposed categorization system?

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

11. What would you change?

12. How would you organize it?

Thank you

Questionnaire about a categorization system on design approaches characteristics

This questionnaire is about a categorization system derived from the coding analysis of 6 designers' interviews. The analysis of the characteristics of designers' approach to design led to the following categories. With this questionnaire we would like to know your perspectives on the categories and weather they make sense and are meaningful to you. We ask you how far you agree with each statement.

Table 1. Structure of the categorization system

Coding dimensions	Categories of Substance (Adapted from Aristotle)	Sub-categories
Environment	*Place*	Structure, Values, Vision
Team	*Relation*	Role, Collaboration, Communication
Designer	*Essence*	Purpose, Concerns, Values, Type of problems
	Passion	Motivation, Emotion
Management	*Time*	Planning, Happening, Decision
	Situation	Client, Resources, Complexity
Process	*Quantity*	Design elements, Design tools
	Quality	Procedure, Strategy, Finding direction, Flow Solution conceptualization, representation and materialization
Performance	*Habit*	Attitude, Learning processes, Cognitive processes
	Action	Cognitive retrieval mechanisms, Heuristics

The dimension Environment entails the category Place and addresses the working place and its environment characteristics, cultural values as well environmental issues in a broad and societal sense. Interviewees show invariant characteristics regarding two sub-categories: Structure in clusters of codes such as, Horizontal approach to people, Challenging company, Space to give and exchange ideas and do a good work, Personal accomplishment in teamwork, and Keep the person active and aware; and Values, in clusters of codes such as, Liberty of saying, Freedom to think and explore, Opinion recognition, Individual reliability and More engagement.
The dimension Team entails the category Relation and addresses the teamwork and designers' individual and team roles. Invariants regard three sub-categories: Team role in clusters of codes such as, Add suggestions as user and professional, Competence recognition and Contribute to define the value of the result; Collaboration, in clusters of codes such as, Sharing, Personal and team engagement, Converge to the same objective; and Communication in clusters of codes such as, Willing to listen, Discussion and Focus.
The dimension Designer entails two categories:
The category Essence that addresses the designers' essential aspects such as, purposes, concerns, values and the type of design problems they deal with. Invariants regard four sub-categories: Common purposes in clusters of codes such as, Knowing the problem context, Project objectives and target group, Learning from the process, Quality and reliability of final result; Concerns in clusters of codes such as, Project feasibility, Knowing each one team role, Planning and Solution improvement; Values in clusters of codes such as, Cooperation, Experience, Integration, Inclusion and Simplicity; and common Design problems in clusters of codes such as, Structuring the problem or the solution and Situations that influence the work of all.
The category Passion addresses feelings and motivations that include emotions and beliefs. Invariants regard two sub-categories: Designers share contrasting Feelings in clusters of codes such as, Enthusiasm and Tiredness, and Motivations in clusters of codes such as, Learning and Personal interest for projects.
The dimension Process entails two categories:
Quantity and Quality that address design elements, methodology and solution. Examples of invariants regard three sub-categories: Design elements in clusters of codes such as, Alphanumeric representations and Structural relations; Finding direction in clusters of codes such as, Mental scheme; and solution representation in clusters of codes such as, Mental and Physical sketch.
The dimension of Management entails two categories:
The category Time relates to aspects of planning, happening and decision in the design process. Example of invariants regard three sub-categories: Planning in clusters of codes such as, Know planning information from the project manager; Happening in clusters of codes such as, Not possible to have everything clearly defined early; and Decision in clusters of codes such as, Commit to the decision on the final solution.
The category Situation relates to aspects of the problem situation, such as client, resources and complexity. Invariants regard three sub-categories: the Client in clusters of codes such as, Inform on project feasibility; Resources in clusters of codes such as, Cope with available elements and persons; and Complexity in clusters of codes such as, Complex projects that require more work and time in structuring.
The dimension of Performance entails two categories:
The category Habit relates to permanent actions of designers. Examples of invariants regard three sub-categories: Attitudes in clusters of codes such as, Being positive, being flexible, Experimenting, Clarify doubts and Open mind; Learning processes in clusters of codes such as, Learning through mistakes, Reuse of knowledge and solutions; and Cognitive processes in clusters of codes such as, Thinking, Analysis and Imagining.
The category Action relates with designers transitory actions to solve more persistent and difficult problems. These actions are related with the sub category of Cognitive retrieval mechanisms. Examples of invariant clusters of codes are, Awareness, Questioning, Proposing, Asking what is missing, Risk assessment, Opportunity recognition, Control recognition, Limits recognition and Give time. Designers share several cognitive retrieval mechanisms to improve personal and solution performance.

Categories	Criteria	Please indicate to what extent do you agree with the categorization of each of the criteria to each category? Doesn't fit / Fit				
		1	**2**	**3**	**4**	**5**
Environment ***Place***	Structure, Values and Vision					
	Is there any criterion missing in the category? Please fill in.					
Team ***Relation***	Role, Collaboration, Communication					
	Is there any criterion missing in the category? Please fill in.					
Designer ***Essence/Passion***	Purpose, Concerns, Values, Types of design problems					
	Motivation and Emotion					
	Is there any criterion missing in the category? Please fill in.					
Management ***Time/Situation***	Planning, Happening, Decision					
	Client, Resources, Complexity					
	Is there any criterion missing in the category? Please fill in.					
Process ***Quantity/Quality***	Design elements, design tools					
	Procedure, Strategy, Direction, Flow, Solution					
	Is there any criterion missing in the category? Please fill in.					
Performance ***Habit/Action***	Attitude, Learning processes, cognitive processes					
	Cognitive retrieval mechanisms, heuristics					
	Is there any criterion missing in the category? Please fill in.					

1. Structure, Values and Vision in the working environment play an important role in designers' approach.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

2. Roles, Collaboration, Communication in team are relevant to define designers' approach.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

3. Purposes, Concerns, Values, Types of design problems are crucial to designers' approach.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

4. Motivation and Emotion are important in designers' approach.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

5. Planning, Happening, Decision are important criteria to design management.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

6. Clients, Resources, Complexity are important criteria to design management.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

7. Design elements, design tools are important in the design process.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

8. Procedure, Strategy, Direction, Flow, and Solution are important in the design process.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

9. Attitude, Learning processes, cognitive processes are important in designers' performance.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

10. Cognitive retrieval mechanisms and heuristics are important in designers' performance.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

11. What would you change in the categorization system?

12. How would you organize it?

Thank you

Questionnaire about a categorization system on designers’ drivers to prioritize values in decision-making

This questionnaire is about a categorization system derived from the coding analysis of 16 designers’ interviews. The analysis of what designers prioritize and value towards decision-making led to the following codes and categories further illustrated. With this questionnaire we would like to know your perspectives on the categories and weather the criteria makes sense and is meaningful to you. We ask you how far you agree with each statement.

Categories	Criteria	Please indicate to what extent do you agree with each of the criteria to each category? If you think a criterion doesn't fit the category please indicate other. Don’t agree				Agree
		1	2	3	4	5
Emotion-based	Interest, like what I do					
	The sensations to transmit to people					
	Feeling of uncertainty					
	Start seeing results					
	Challenging opposition					
	Personal and team emotional evaluation along the process					
	Is there any criterion missing in the category? Please fill in.					
Intuition-based	Feeling that something is wrong					
	Feeling certainty about a choice without argument					
	Feeling of certainty in changing priorities					
	Action driven experimentation					
	Individual or external sources of inspiration					
	Is there any criterion missing in the category? Please fill in.					
Rational-based	Know-how, specific knowledge					
	Project management					
	Design purpose, goals and direction of procedure towards the solution					
	Ethics					
	Users satisfaction					
	Design problem context, situation and circumstances					
	Redo, fine-tuning or reviewing					
	Undeveloped Knowledge					
	Is there any criterion missing in the category? Please fill in.					
Experience-based	Framed design choices					
	Evaluation and association with results and processes from the past					
	Looking for references					
	Open mind for new solutions					
	Experiencing the design situations, foreseeing the experience through simulation					
	Foreseeing difficulties					
	Is there any criterion missing in the category? Please fill in.					
Constraint-based	Time limitation					
	Financial limitation					
	Technology conditions					

	New policies limitations					
	Client restrictions					
	Cultural conditions					
	Is there any criterion missing in the category? Please fill in.					

1. Emotions play an important role as drivers of priority values in designers' decision-making. Do you think emotion is important enough to be a category of designers' drivers of priority values in decision-making?					
❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree
2. Intuition has a relevant role as driver of priority values in designers' decision-making. Do you think intuition is important enough to be a category of designers' drivers of priority values in decision-making?					
❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree
3. Rationality has a crucial role as driver of priority values in designers' decision-making. Do you think rationality is important enough to be a category of designers' drivers of priority values in decision-making?					
❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree
4. Experience has a relevant role as driver of priority values in designers' decision-making. Do you think experience is important enough to be a category of designers' drivers of priority values in decision-making?					
❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree
5. Constraints are a fundamental part of the design process and drivers of priority values in designers' decision-making. Do you think constraints are important enough to be a category of designers' drivers of priority values in decision-making?					
❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree
6. How far do you agree with the proposed categorization system?					
❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree
7. What would you change?					
8. How would you organize it?					Thank you

Questionnaire on a categorization system of critical situations and crucial actions in design

This questionnaire is about a categorization system derived from the coding analysis of the interviews of 25 designers and 28 meetings. The analysis of critical situations and crucial actions in design led to the following challenges and categories. With this questionnaire we would like to know your perspectives on the categories and weather the challenges make sense and are meaningful to you. We ask you how far you agree with each statement.

Critical situations and Crucial actions in Design

Sources	Challenges	Examples of observed behavior in critical situations	Examples of observed successful behavior in crucial actions
Dosage	Adequacy	Missing criteria	Look for essential criteria
	Balance	Over/ under dosage	Make things matching
Planning	Probability	No probability evaluation	Preparedness
	Anticipation	No view of the future	Foreseeing opportunities
Framing	Orientation	Difficulty to choose	Reflected choice
	Focus	Stuckness	Convergence
Information Assessment	Surprise	Missing opportunities	Opportunistic procedure
	Knowing	Clients that do not know what they want	Look for information
	Transparency	Difficulty to grasp the features of a problem	Searching for indicators
Information Transfer	Communication	Confirmation bias	Transparent communication
	Exchange	“Tunnel view”	Awareness of the need for sharing information
	Documentation	Not keeping record of sub-results	Keeping record of sub-results
Interdependency	Interfaces	Acting without reference to others involved	Awareness of the different interfaces involved
	Suspension	Missing feeling of competence	Take time for decisions and keep in mind long and short term consequences
Envision	Open up solutions	Difficulty to think into the future	Generating alternatives
	Representation	Difficulty to represent a concept	Providing clear examples, good graphics and visual proposals.

Dosage - refers to the need to find adequacy (enough in quantity or good enough in quality for a particular purpose or need) or balance (emotional, economical, aesthetical, or negotiable stability) in the quantity and quality of different activities and measures, in order not to overdo or be underdone.
Planning - refers to situations which need an action plan for the future regarding the extent to which results are likely (probability), and the extent to which something is expected or predictable and take action in order to be prepared (anticipation).
Framing - refers to situations that hinder or provide orientation (direction to proceed) and focus (concentrating interest, to adapt or adjust so that things can be seen clearly), that need to be framed or reframed.
Information assessment - refers to the awareness of the relevance of a situation that shows the absence or latest information and that relate to: moments of surprise (denoting something made, done, or happened unexpectedly), transparency (difficult to perceive or detect) and knowing (what is known or not about facts, information, and skills acquired by a person through experience or education), which create ambiguity and uncertainty that can hinder the process but can also be beneficial to generate alternatives and overview.
Information transfer – refers to situations where the transference of information requires to deal with different challenges such as: communication (the successful conveying or sharing of information, ideas, feelings, news, through the means of sending or receiving information), exchange (an act of giving or doing something to somebody and receiving something in return) and documentation (the act on recording material that provides official information or evidence or that serves as a record).
Interdependency – refers to situations where the need to establish or undo interdependencies, is made through the creation and recognition of interfaces (a point or moment where two systems, subjects, organizations, etc., meet and interact, such as people, companies, expertise, software, technical limitations) or suspension (the action of suspending someone or something or the temporary prevention of something from continuing or being in force or effect).
Envision - refers to situations that request to start imagining future possibilities regarding the design goal, solution or sub-solutions, taking different perspectives, giving form to mental images or making something visible to the eyes through representation and feasibility assessment. Such situations can hinder or further the design process regarding the extent to which such mental or physical images of solutions are created with flexibility, taking different perspectives, providing a wider ideation space to be unfolded, and solutions to come into view.

Categories	Challenges	Please indicate to what extent do you agree with the categorization of each of the criteria to each category? Doesn't fit				Fit
		1	2	3	4	5
Dosage	Adequacy					
	Balance					
	Is there any criterion missing in the category? Please fill in.					
Planning	Probability					
	Anticipation					
	Is there any criterion missing in the category? Please fill in.					
Framing	Orientation					
	Focus					
	Is there any criterion missing in the category? Please fill in.					
Information Assessment	Surprise					
	Knowing					
	Transparency					
	Is there any criterion missing in the category? Please fill in.					
Information Transfer	Communication					
	Exchange					
	Documentation					
	Is there any criterion missing in the category? Please fill in.					
Interdependency	Interfaces					
	Suspension					
	Is there any criterion missing in the category? Please fill in.					
Envision	Open up solutions					
	Representation					
	Is there any criterion missing in the category? Please fill in.					

1. Actions for adequacy and balance play an important role in designers' activity.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

2. Actions of anticipation and probability are relevant in designers' activity.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

3. Actions of finding orientation and focus are crucial in designers' activity.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

4. Actions of coping with surprise, of knowing and searching for transparency are important role in designers' activity.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

5. Actions of communicating, exchange and documenting are important in designers' activity.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

6. Actions of establishing interfaces or suspending interdependencies are important in designers' activity.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

7. Actions of open up solutions and representation are important in designers' activity.

❒ Completely disagree	❒ Disagree	❒ Tend to disagree	❒ Tend to Agree	❒ Agree	❒ Completely agree

8. What would you change?

9. How would you organize it?

Thank you

Curriculum vitae

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Place of birth: Luanda, Angola

Sonia Vieira graduated from FAUP, Faculty of Architecture of the University of Porto in 2001. The experience as an Architect led her to seek complementary knowledge with a Master in Industrial Design, degree received by FEUP, Faculty of Engineering of the University of Porto in 2006. She is a researcher at the Unity of design and conceptual validation at IDMEC-FEUP, since 2004. She started her Ph.D. project on the translation of the Lean Principles into design in late 2007. She presented her research at several international conferences in design and product development, such as, IASDR World conference on Design Research, ICED International Conference in Engineering Design, DTRS8 Design Thinking Research Symposium, CADMC Cambridge Academic Design Management Conference, Design Conference, EIASM International Product Development and Management Conference, IDEMI Integration of Design, Engineering and Management for Innovation, and Icord International Conference on Research into Design. She teaches Culture of Design and Usability in the Master and specialization courses in Industrial Design at FEUP, UPorto. She is an active member of the Design Society's Special Interest Group on Risk Management Processes and Methods in Design.

List of Publications

Ph.D. research in Journals

Vieira, S., Fonseca, T., Badke-Schaub, P., Fernandes, A., *Framework of Awareness to Critical Situations in Design and Product Development: A Lean Thinking Approach to deal with uncertainty and risk.* Submitted to Journal of Product Innovation Management.

Ph.D. research in conference proceedings

Vieira, S., Fonseca, T., Badke-Schaub, P., Fernandes, A., (2013). *Lean Principles as Elements of a Pattern of Behavior.* International Conference on the Integration of Design, Engineering and Management for Innovation, 4-6 September, Porto, Portugal.

Vieira, S., Fonseca, T., Badke-Schaub, P., Fernandes, A., (2013). *Framework of Awareness to Critical Situations in Design and Product Development: A Lean Thinking Approach to deal with uncertainty and risk.* 20th International Product Development and Management Conference, 23-25 June, ParisTech, France.

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